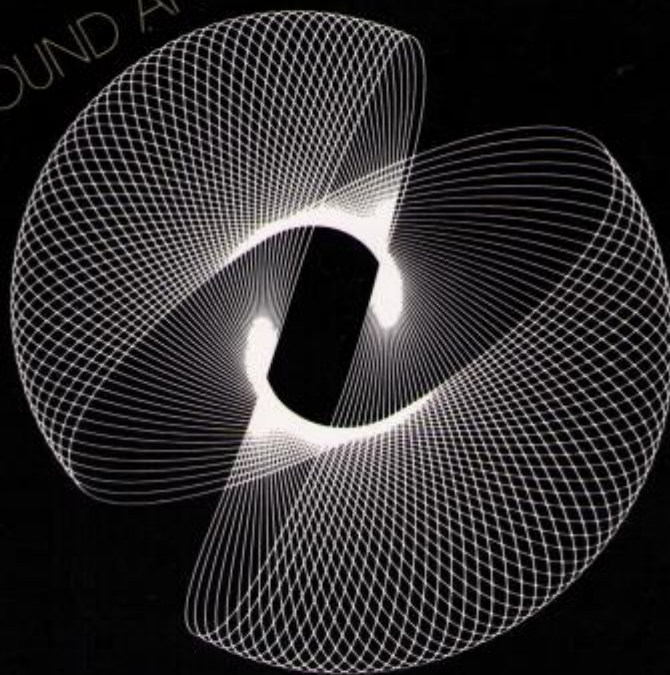


SOUND AND LIGHT PHENOMENA



a Study of Historical  
and Modern Occurrences

SANDRA CLAFLIN-CHALTON  
GORDON J. MACDONALD

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by  
SANDRA CLAFLIN-CHALTON  
and  
GORDON J. MACDONALD



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## ABSTRACT

Approximately two thirds of 594 separate unusual noise events reported along the east coast of Canada and the United States in the period December 2, 1977, to May 31, 1978, can be attributed to the operation of supersonic aircraft. Most of the remaining 181 events are believed to have a natural origin. This conclusion is in accord with thousands of historical accounts of booms not associated with thunderstorms and related weather activity. The historical association of some booms with earthquakes suggests that the booms may result from disturbances in the earth's crust leading to explosive releases of gases some of which may be combustible. In many cases, for example the Ramapo fault earthquake of June 30, 1978, the sounds precede the earthquake shock by seconds. In other cases, booms are heard for long periods prior to an earthquake, while other booms show no clear relation to observed earthquakes.

## ACKNOWLEDGMENT

Many people have assisted us by providing newspaper articles and citizen observations, particularly: Ms. Hattie Perry of the Energy Awareness Center, Barrington, Nova Scotia; Dr. Joyce Bagwell of Baptist College, Charleston, South Carolina; Mr. Ernie Jahn of the National Investigative Committee of Areal Phenomena; and Mr. Jack Brown of the Naval Research Laboratories. In addition, our thanks to the following newspaper staff members for searching their files for relevant articles: In New Jersey; *Asbury Park Press*; *Herald News*, Clifton; *Bergen Evening Record*; *The Reporter*, Toms River; *The Daily Journal*, Elizabeth; *Daily Observer*, Long Branch. In South Carolina; the *News and Courier*, Charleston. In California; the *Santa Barbara News Press*. In Canada; the *Chronicle Herald*, Halifax, Nova Scotia; and *Standard-Freeholder*, Ottawa, Ontario. Our thanks to the librarians at the Charleston, South Carolina Public Library and the Santa Rosa, California Public Library for their assistance and to Ms. Ernestine Jones of the U.S. Geological Survey, Reston, Virginia. We would also like to express our appreciation to members of the Skidaway Institute of Oceanography, Georgia; the National Marine Fisheries Divisions in Beaufort, North Carolina and Miami, Florida; and Dr. Widmir of the New Jersey Bureau of Geology and Topography for their interest at the inception of this study.

Our special thanks to Ms. Linda Morris for her invaluable and untiring support throughout this effort and Ms. Malinda Kerr for her research work.

We wish to particularly acknowledge the contribution of Professor Thomas Gold of Cornell University. His numerous suggestions and comments have been invaluable.

## FOREWORD

Press reports throughout December 1977 and January 1978 of intense booming noises in New Jersey, the vicinity of Charleston, South Carolina, and the southwest tip of Nova Scotia, prompted great public interest in the "East Coast Mystery Booms." While there are scattered reports of booms in earlier months, events on December 2, 1977, in New Jersey and Charleston, triggered many reports during the next two months after which press interest waned. The present investigation analyzes these reports and similar observations made over the past three centuries.

Concern, even fear, by the public prompted Senator Harrison Williamson (N.J.) to request a White House investigation into the causes of the booms. Frank Press, Director of the Office of Science and Technology Policy, referred the problem to the Defense Department, which in turn gave lead responsibility to the Naval Research Laboratory (NRL). The resulting study by NRL concluded that military aircraft operating at supersonic speed in unusual weather conditions which amplified and reflected the aircrafts' normal sonic carpet boom over abnormally long distances caused the booming noises.<sup>1</sup>

Jeremy Stone of the Federation of American Scientists, examining the same data employed by NRL suggested that flights of the British/French Concorde were responsible for all the events from Nova Scotia to Charleston.<sup>2</sup> This position was later modified to conclude that the booms in Nova Scotia were attributable to Concorde, and suggest that the Charleston and New Jersey events might have a similar origin.<sup>3</sup>

The NRL report examined a host of alternative explanations, including: Nuclear explosions, military research and development activities, military or civilian use of ordnance and high explosives, ship disasters, USSR ship operations, geophysical exploration, antipodal events, missile launches and re-entries, low-altitude satellites, Concorde, high-altitude aerosols, meteorites, winter lightning, direct seismic generation, biogenic and tectonic methane.<sup>4</sup> The NRL Study concludes that all alternative man-made explanations can be excluded except Concorde in Nova Scotia and military aircraft in New Jersey and Charleston, and that the natural alternatives are highly unlikely.

We have reviewed the data used to support the military aircraft and Concorde theories and find that these explanations cannot in any way account for about 30 percent of the 594 separate events\* reported during the period December 1977 through May 1978. We agree with

\*An event is defined as a set of observations. The total number of separate observations is in the thousands.

NRL that alternative artificial sources can be ruled out and conclude that the majority of 181 events which are unrelated to aircraft operations have a natural origin.

In addition to the numerous explanations noted, the NRL Study cursorily discusses historical phenomena reported in the Nineteenth Century. The observations of the previous century closely parallel those reported today. NRL concludes that the historical sounds were heard outside, and are not the same as the present sounds which NRL claims are heard predominantly inside. As will be demonstrated, this conclusion does not agree with the historical accounts.

The recently observed events lead to questions as to the origin of the hitherto unexplainable historical sound phenomena, and to the need for continuing work in understanding sounds generated by modern man-made sources.

This study reviews in detail historical sound phenomena, current observations, and known work on low frequency waves and related man-made sources of unusual sounds. It is intended as a starting point for further investigations, not an attempt to explain each and every one of the approximately 600 different groups of observations documented since December 1977.

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## HISTORICAL SOUND PHENOMENA

Unexplainable booms, blasts, explosions, sounds similar to heavy artillery firing, or wagons on rough roads are not new phenomena. References of unusual sounds, not thunder, are found as far back as the Old Testament.

It was the Eighteenth and Nineteenth Century naturalists and explorers who have left the most systematic records of curious natural events. Numerous journal entries contain accounts of unexplainable noises in Europe, North and South America, Australia and the Far East. Interest in the origin of earthquakes stimulated historical research and cataloguing of thousands of earthquakes and associated phenomena, including booming noises. David Milne<sup>5</sup> and Robert Mallet<sup>6</sup> compiled exhaustive lists. Van Humbolt<sup>7</sup> and Lewis and Clark<sup>8</sup> wrote of unusual natural noises following exploratory expeditions. Sir George Darwin, son of Charles Darwin, a leading theoretical geophysicist of the Nineteenth Century, requested observers of various noise phenomena to submit their descriptions to him for compilation and discussion.<sup>9\*</sup> His request has resulted in the most complete accounts of natural noise phenomena available to us today. A selection of historical accounts of booms and lights is given in Appendix II. Appendix III provides a brief overview of phenomena associated with earthquakes.

Gold and Soter<sup>10</sup> have shown that it is useful to characterize natural noise phenomena in terms of the seismic setting of the region in which sounds have been observed. We adopt a slightly modified classification to discuss the historical reports.

- *Noises without earthquakes or other associated natural events occurring in regions that are considered relatively seismically inactive.* In Guanajuato, a Mexican plateau city, "subterranean thunder" has been observed with alternating slow thunder rumblings and sharp claps noted over a month's period. No trembling or earth movements were observed and the noises simply ceased.<sup>11</sup> Dull distant detonations occurring irregularly have been observed all along the French/Belgian coast without any notice of seismic or other natural events.<sup>12</sup>
- *Noises observed irregularly over many years in an area of occasional tectonic activity, without any obvious connection between seismicity and noises.* "The first one of these sounds I heard under Gannet Rock was about fifty years ago (written 1898) . . . about 2 a.m. I was reading when bang went the shock of what seemed to be like a 24-pounder cannon. I went outside to investigate and found a clear,

\*Appendix II reproduces Darwin's article.

dark night, with few clouds and light winds. It was, I think in October."<sup>13</sup> Other accounts of sounds in this same area (coast of New Brunswick, Nova Scotia) suggests atmospheric, not subterranean, origins. An intense earthquake of Modified Mercalli scale VIII\* occurred in the Bay of Fundy, October 1869. The sounds were heard before and after, seemingly unaffected by this quake and other lesser earthquakes during the last two centuries.

The Moodus sounds in East Haddam, Connecticut, have been reported since settlers first arrived, and probably occurred even earlier, as the sounds are part of local Indian folklore. "The famous and mysterious disturbances . . . 'Moodus Sounds' are being heard again (1897). For twenty years, up to 1729, the villagers . . . heard the noises continuously, 'shaking houses and all therein'. They were again heard in 1852 and 1885. On the recent occurrence (1897) there was a sound like a clap of thunder . . . a day later there was a crashing sound like heavy muffled thunder, and a roar."<sup>14</sup> The sounds were again reported in 1940.<sup>15</sup> East Haddam suffered a MM VIII earthquake in 1791 with smaller earthquakes in 1792, 1793, 1794, and 1805, but there has been only minor seismic activity since then. Sounds were reported without noticeable ground movement in East Haddam during the 1925 earthquake.

- *Noises which occur at least one hour prior to an earthquake.* ". . . people throughout Giles County (Virginia) were much disturbed by subterranean noises, and all day Monday (May 31, 1897) detonations like distant artillery were heard throughout the country. 'Earthquake sounds are reported to have begun 4 weeks earlier, on May 3'. . ."<sup>16</sup> The earthquake, intensity MM VI occurred at 13:58, May 31. In the case of the East Anatolian earthquake of November 1976, "noises resembling thunder were heard several times during the week preceding the quake . . . Hidermentes, directly on the fault trace and where it cuts the lake, there were reports of noises coming from the lake (foreshocks, gas release, microfracturing?) during the same period."<sup>17</sup>
- *Noises momentarily preceding or accompanying an earthquake.* At the time of the western North Carolina earthquake in May 1957, "Loud, roaring earth noises were heard in many places."<sup>18</sup> "In Falmouth, there was a gradual rumble that ended abruptly like an explosion"<sup>19</sup> during the earthquake at Lake Ossipee, New Hampshire, December 1940. "The shock (earthquake) of the 23rd (October 1839, Comrie, Scotland) was accompanied with a noise in nature and intensity indescribably terrific,—that of water, wind, thunder, discharge of cannon, and the blasting of rock, appeared combined."<sup>20</sup> Telephone callers described to the Mahwah Police,

\*See Appendix I for a description of the Modified Mercalli scale.

loud explosive sounds near Mount Ramapo just before the Mahwah, New Jersey earthquake, June 30, 1978.<sup>21</sup>

Sounds which are heard often enough to have local names generally fall into the first two categories, that is noises not directly associated with tectonic or seismic activity. Figure 1 shows the locations and names for the more well-known sounds in the North Atlantic region.

However, mysterious noises are by no means confined to the Atlantic. Numerous British naturalists heard and later described their impressions of the phenomena called the "Barisal Guns" around the Ganges Delta and Assam. Additional reports from Australia, the Middle East and Africa show a global distribution of unexplained sounds. A large number of the historical noises are associated with bodies of water. The "Mist Pouffers," "Sounds of Morecombe Bay," "Gouffres," and "Sea Farts" are heard on or near the ocean; the "Guns of Seneca," "Lough Neagh," and "Bosumtwi" are heard near or over lakes. But, there are also reports of noises on land associated with bodies of water--Comrie, Scotland; Australian "Barisal Guns"; and the Connecticut "Moodus Sounds."

It is not possible to tell from descriptions alone if the nature of the noises vary from over water or land. Rumbings, explosions, cannon-shots, ack-ack shells, pistol shots, carriages on rough roads, dull thuds, are all used to describe what is being heard. The "Barisal Guns" have the distinction of being observed as triple detonations, whereas most other examples are heard as a single sound without a distinguishing signature. In most cases, there are reports of the sound being heard both indoors and outdoors.

Given the richness of reports of sounds heard in the past, the question arises as to why the natural sounds are no longer heard. Provided that at least some fraction of the hundreds of accounts describe real events, the most logical answer is the noises have not stopped, but have been incorporated into the background noise of modern society. The fact that Cornell University students studying late at night still hear the unexplained booming noises from Lake Cuyuga suggests that this might be so.<sup>22</sup>

Factories of the Nineteenth Century were undoubtedly as loud as any today, but Twentieth Century developments have added a new dimension to sound--sounds originating from mobile sources. Motorized conveyances (motorcycles, cars, trucks, bulldozers, aircraft, speed boats) have carried sounds far outside more contained industrial centers.

With the addition of so many artificial sounds it becomes increasingly difficult to distinguish specific natural noises. For example, a sonic boom may manifest itself as deep rumbling, a dull thud, a boom, or be mistaken for actual distant thundering. Expectation of industrial



FIGURE 1  
HISTORICAL NOISE PHENOMENA

life noises causes observers to assume a man-made origin. The interesting part of the winter 1977-1978 events is the reporting locations. Southwestern Nova Scotia has little industry, and on the land-bridging islands, prohibits motorized conveyances. Here sounds are more distinguishable than in New York City. The Isle of Palm, James Island, and Sullivan's Island, all near Charleston, also have the convenience of being in areas without major industrial sounds. This is the case in a number of reporting locations from New Jersey. The noises reported from central Charleston and Newark must have been intense to have been noted above urban city backgrounds.

It is unfortunate that there are few centers to which unusual noise phenomena can be reported. Just before the earthquake along the Ramapo Fault, June 30, 1978, several telephone calls were made to the Mahwah, New Jersey, Police Station describing explosions near the base of Mount Ramapo. Officers are able to take the reports, but do not have the manpower to investigate, nor does a center exist to receive and evaluate reports. All too often such reports from uncritical observers are considered unscientific and ignored. Without the considerable press interest in the recent events, it is unlikely that any study would have been conducted.

## CURRENT OBSERVATIONS

### BACKGROUND

Three distinct areas have been most affected by the reported sound phenomena since early December 1977. People of the New Jersey coastal areas reported sounds of intense explosions beginning December 2, 1977, and continuing intermittently until January 19, 1978; although reports of light phenomena continued to January 26. Charleston, South Carolina residents noted widespread heavy vibrations beginning December 2, 1977, sometimes accompanied by loud noises. The last reported incident was May 3, 1978, but the most widespread and intense Charleston occurrence was February 21. Reports of both heavy vibrations with accompanying explosions and rumblings, and booms or blasts without vibrations, began in Southwestern Nova Scotia around January 1, 1978, and are continuing as of late August, the greatest number of reports occurring in February.

Isolated explosions or blasts have been reported during 1978 in Connecticut and Virginia. A study completed in 1976 by Stewart and Taylor<sup>23</sup> reviewed the dull explosions heard for many years by residents south of the Cape Fear Arch area of the North Carolina coast. Descriptions from the North Carolina region closely resemble similar reports beginning in early March 1977 along the Charleston coastal area.<sup>24</sup>

### DATA SOURCES

This study, the NRL investigation, and other reviews of sound observations are based primarily on citizen reports together with acoustic and seismic recordings provided by Weston Observatory of Boston College, Lamont-Doherty Laboratory of Columbia University, and Baptist College of Charleston.

The validity of citizen reports becomes a subjective matter. Are some observers more credible than others? The NRL investigators limited their study to events which were both observed by citizens and recorded on acoustic or seismic equipment. In a number of incidences acoustic or seismic recordings exist, but citizen observations are lacking; it is impossible to know whether sounds were heard and simply not reported or not heard.

To investigate unusual occurrences, all available data must at least be reviewed. Some may be easily explainable, such as the example of a series of reports at 0200 on December 22, which was an explosion of a transformer fuse near Tom's River, New Jersey. To suggest, however, that most anomalous events, (events which do not coincide with the prevalent theory) can be explained if only lengthy investigations are

pursued<sup>25</sup> does not leave much room for further study. These anomalous events may, in fact, be just the exceptions which provide new scientific insight into areas previously overlooked. In this study, the data bases for each of the three major areas of concern are presented and analyzed using all available accounts.

#### Charleston and Vicinity

Mrs. Joyce B. Bagwell, and her staff at Baptist College, Charleston, South Carolina, went back through their notes and log books, providing MITRE with citizen reports and seismic recordings since March 1977. \* Mrs. Bagwell is Assistant Professor of Chemistry - Geology and Principal Investigator of the Baptist College seismic network. The data she provided are supplemented with some newspaper accounts and several events reported by NRL investigators. The set of observations beginning December 1, 1977, are presented in Appendix IV.

#### New Jersey

Instrumented observation of the New Jersey events were obtained from seismic recordings taken by the Weston Observatory and from acoustic and seismic signals recorded at Lamont-Doherty as provided to NRL,<sup>26</sup> and citizen observation. Most of the citizen observations were provided to MITRE and NRL by the National Investigative Committee for Areal Phenomenon (NICAP). This non-profit organization is one of the few groups in the United States to which observers of unusual areal phenomena (meteorological, sounds, lights, etc.), can report. MITRE was referred to NICAP at the beginning of the study in January, by the Public Affairs Office of the National Aeronautics and Space Administration (NASA).

The data which appeared in Appendix 2 of the NRL report is identical to the original worksheets provided by Ernie Jahn of NICAP to MITRE and J. Brown of NRL. These citizen reports, Weston Observatory seismic recordings, Lamont-Doherty acoustic signals, and some newspaper accounts, form the basis for the New Jersey data listed in Appendix V.

\*Two types of instrumentation provide mechanical recordings of sound waves. On a seismic net, recordings in the vertical direction without associated horizontal movement suggest atmospheric origin as opposed to earth motion. Acoustic detection is done through an array of microphones which record low frequency (inaudible) components of sound waves. Only seismic recordings are available for the Charleston events. Many of the New Jersey events were recorded seismically and acoustically. Only citizen reports are available for Nova Scotia.

#### Nova Scotia - Shelburne County

The largest collection of observations of the recent events comes from citizen reports gathered by the Energy Awareness Center, an ecology group in Barrington, Nova Scotia. Mrs. Hattie Perry, head of the Center, and Mrs. Charlene Stewart, also of the Center, have provided an invaluable set of citizen observations. The intensity of the almost daily barrage of sounds experienced by the citizens in Shelburne County and surrounding areas, prompted a unified action by these concerned people with the purpose of bringing the severity of the problem to the attention of the Canadian authorities. A toll-free telephone line to the Center encouraged immediate reporting response by people in the area. Lighthouse keepers also provided records which were added to the events being collected in Barrington. The complete data record, from the beginning of January through May 1978, is presented in Appendix VI.

#### DATA ANALYSIS

Several thousand individual observations of sound and light phenomena have been reported during the period from December 1, 1977, to the end of May 1978, in the three regions investigated. Descriptions of these events range from a soft distant boom to an intense vibration of buildings, houses, and ground. In many instances, more than one citizen or measured observation is reported for a specific time and region. To simplify the data analysis, simultaneous observations occurring in the Nova Scotia, Charleston or New Jersey areas are grouped together to form one event for the particular area in which the reports occurred. This grouping reduced the total number of observations to 594 events over the six-month period.

Although initial reaction to the simultaneous events of December 2, 1977, in both New Jersey and Charleston suggested a common cause or source, continuous review of incoming data after this date does not support this conclusion. For analytic purposes, Nova Scotia, New Jersey, Charleston and other incidents are each treated separately. Independent regional analysis does not preclude the possibility of similar causes or sources, but as pointed out in the Foreword of this paper, the purpose is not to propose a single explanation, but to present all known data together with possible explanations of the natural events.

The data have been divided into three Appendices (IV, V, and VI) corresponding to each of the regions being studied. Table I is representative of the way in which the data have been tabulated.

In many instances, descriptions accompany reports, such as "rattling windows, two booms, shook home," and so forth. A simple abbreviated code has been devised and added following the place of observation for easy reference (definition of the code is attached to the Appendices).



TABLE I  
NEW JERSEY, CHARLESTON, AND NOVA SCOTIA DATA

Date	Code*	Code**	Observation	Calculated**	Concorde**	Military*	
(Day of Week)	Military Aircraft (Yes/No)	Concorde Flights (C,A,N)	Place of Observation	(Local Time)	Time (Local)	Flight (EST)	Flight (EST)

\*Military aircraft flights are unavailable for Nova Scotia  
\*\*Concorde only used for Nova Scotia

After the release of the NRL study in March 1978, and a rebuttal by Stone of the Federation of American Scientists, supersonic aircraft (military and Concorde) became the focal point of continuing investigation. Two new independent studies, one by NRL,<sup>27</sup> and a second by JASON<sup>28</sup> conclusively show that the Concorde cannot be responsible for audible events in Charleston or New Jersey; therefore, these two areas are only compared with military operations. A detailed discussion on Concorde is presented later in this book.

The military aircraft flight times used are from the NRL study.<sup>29</sup> If supersonic aircraft are known to be in the Warning Areas where the event occurred, a "Yes" is entered in the column entitled "Military Aircraft" and the times the aircraft are aloft are entered under "Military Flight."

The Nova Scotia data can only be compared to Concorde flights, as the actual times Canadian military planes are flying have not been made available. For Nova Scotia, calculated times when a boom should be heard are developed from actual arrival and departures for Dulles Airport, Virginia, and John F. Kennedy Airport, New York.<sup>30</sup> The details of the calculations are given in Appendix VI.

Comparisons are made between the time of observations and calculated times. The Nova Scotia events are placed into one of three categories under Concorde flight code:

- C -represents events within 15 minutes of Concorde;
- A -represents associated events within 30 minutes of Concorde. Associated events may include training maneuvers by military aircraft using the Concorde flights as targets;
- N -represents all other events.

Table II illustrates the time ranges for each category.

TABLE II  
TIME RANGES

Event-Code	Calculated Time	Range
C (Concorde)	1100	1045-1115
A (Associated)	1100	1030-1045 1115-1130
N (Non-associated)	1100	before 1030 after 1130

In addition to the time ranges, events are categorized A (Associated) if the description includes "double boom" as expected for a supersonic aircraft. However, it is possible that some events have been placed in the A category which are, in fact, non-associated with aircraft. Given the available information, it is not possible to identify coincidental events.

The Concorde flight for each calculated time is given in the column entitled "Concorde Flight." To distinguish the airport, arrivals, departures, and airline, all flights are annotated: a = arrival; d = departure; AF = Air France; BA = British Airways; ( ) = Dulles flights; no brackets represent JFK flights; and finally, an asterisk by a Dulles flight denotes a scheduled and not a monitored flight, i.e., aAF0000 = JFK Air France arrival; (dBA0000) = Dulles British Airways departure; and (aAF0000)\* = Dulles scheduled Air France arrival.

From the information developed in this manner the distribution of all events is presented in Table III, for December 1, 1977, to May 31, 1978.

TABLE III

## DISTRIBUTION OF TOTAL EVENTS

Total Number of events Observed and Recorded	New Jersey 101	Charleston 57	Nova Scotia 436
C			143
A			100
N			93
Military*	32	23	-
Non-Military	67	21	-

\*After January 14, data on military aircraft are not available. Events before 0700 or after 2100 are considered non-military; the total number of military and non-military do not add up to the total number of events because of the uncertainty of the nature of the events during the period 0700 to 2100.

## SUPERSONIC AIRCRAFT - THE CURRENT EXPLANATION

Sonic booms - usually a light cracking sound, but occasionally a deeper thud or rattling boom, are familiar to many in this age of supersonic aircraft. A sonic boom results from a sound wave generated off the shock wave made by a plane flying faster than the speed of sound.

A plane flying through the atmosphere displaces the air through which it is traveling, creating a conical shock wave called the Mach cone. The sound waves (sonic boom) are generated perpendicular to the Mach cone, as illustrated in Figure 2.

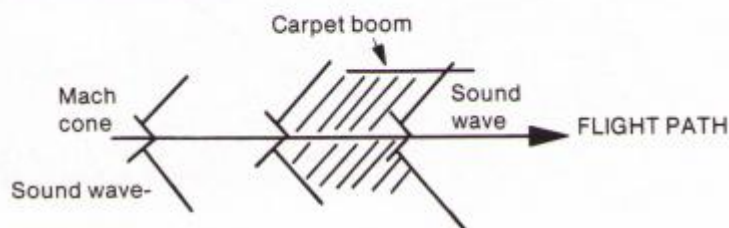


FIGURE 2  
SOUND WAVES

The carpet boom is the direct downward traveling part of the sound wave and under normal conditions would be heard at horizontal distances of about 70-80 kilometers (km) for a Concorde flying at 17.5 km height.

At many points along the flight path these generated sound waves may reach the ground directly resulting in the so-called carpet boom. Normally these waves travel only a few miles so that supersonic aircraft flown over areas such as the desert or ocean do not disturb populated areas.

Intensities of the sound waves depend upon the strength of the shock wave, which in turn depends upon the speed, size and altitude of the aircraft and the atmospheric conditions. A small fighter jet traveling at 1.5 Mach (M) speed (1.5 times the velocity of sound at the plane's altitude) will not create as strong a shock wave and resulting sonic boom as the larger, heavier Concorde jet, flying at the same speed. The great air displacement is one reason why many of the booms experienced in Nova Scotia may indeed be carpet sonic booms from the Concorde flying as far as 160 km offshore. A military plane, on the other hand, would not generate a strong enough shock wave and

resulting sound wave that could travel the same distance without dissipating unless unusual atmospheric conditions prevailed. A maneuvering plane can create a high intensity boom at ground level through focusing of the sound wave. A focused boom or super boom forms when energy imparted into the atmosphere along some segment of the flight path arrives simultaneously at the same point on the ground (See Figure 3). Focused booms can also be generated during acceleration or deceleration.

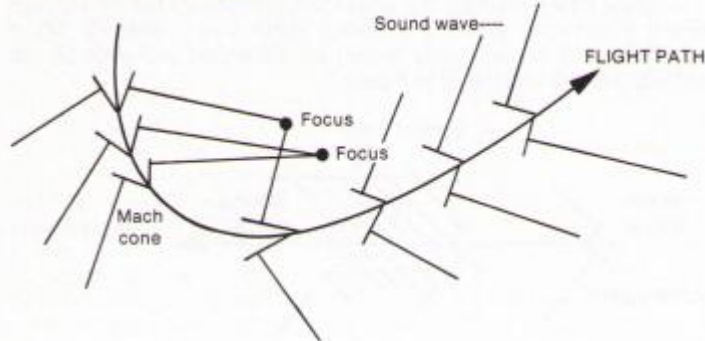


FIGURE 3  
FOCUSED BOOM

H.S. Ribner<sup>31</sup> points out, in his study on reducing focus booms of SSTs, that as a turn is executed at constant speed, the Mach cone becomes unsymmetrically curved inside the turn which causes the sound waves to converge or focus (See Figure 4).



FIGURE 4<sup>31</sup>  
MACH CONE FOCUSED BOOM

Decelerating on the turn or allowing sufficient turning radius can prevent this type of focusing. On the other hand, acceleration or improper deceleration can generate focused booms. Ribner discusses the fact that planes traveling close to the local speed of sound have more difficulty in controlling a focused boom than planes at speeds near 1.7M.

R.A. Wood, among others, has noted that inhomogeneities in the atmosphere can lead to focused booms. "Sonic boom effects are also critically dependent upon the atmospheric conditions through which the shock wave is propagated. These include upper-level wind-speed, vertical wind shears, temperature lapse rates, and to a lesser extent humidity and hydrometers. When these factors combine to deform the shock wave such that convergence of the sound rays result, the energy of the wave is concentrated or focused into relatively small areas."<sup>32</sup>

The sound waves generated by the shock wave initially have a broad frequency spectrum containing energy in both the audible and infrasonic regions. As the sound wave travels through the atmosphere, the high frequency portion of the wave attenuates much more rapidly than the low frequency portion. The attenuation of 1 Hertz (Hz) disturbances is less than 0.001 decibel (db)/km. F.H. Grover has examined the propagation of sound waves generated by the supersonic flight of Concorde. "High frequency components of the N-wave are rapidly attenuated with distance so that the range at which the wave is audible as a boom is of the order of a few tens of kilometers. Very low frequency components of the acoustic waves are, however, able to propagate to much greater distances (300 kilometers on his instruments), because of the temperature and wind gradients by which the atmosphere is effectively stratified, provide ducts through which the larger wave lengths of infrasonic waves can be propagated with low transmission loss."<sup>33</sup> Grover also found that under special atmospheric conditions, Concorde sonic booms had measurable seismic effects as far as 120 km distance from the path.

Liszka at the Kiruna Geophysical Institute in Sweden has recorded infrasonic waves attributable to Concorde flights at distances up to 4500 km.<sup>34</sup> In his work on long-distance focusing, four large areas are identified as potential recipients of the low frequency waves generated by the supersonic aircraft. These are shown on Figure 5.

In summary, a turning maneuver can cause a focusing of sound waves, increasing the strength of the resulting boom. In addition, supersonic aircraft may focus sound waves due to the curvature of the Mach cone. Weather conditions may distort the waves causing the intense focused boom from an aircraft to be carried over long distances.

#### THE NAVAL RESEARCH LABORATORY INVESTIGATION OF EAST COAST BOOMS

After reviewing numerous possible man-made and natural explanations for the blasts, booms and vibrations reported in New Jersey and Charleston, NRL concluded that military aircraft flying at supersonic speeds in restricted zones coupled with unusual weather conditions caused the winter incidents.<sup>35</sup>

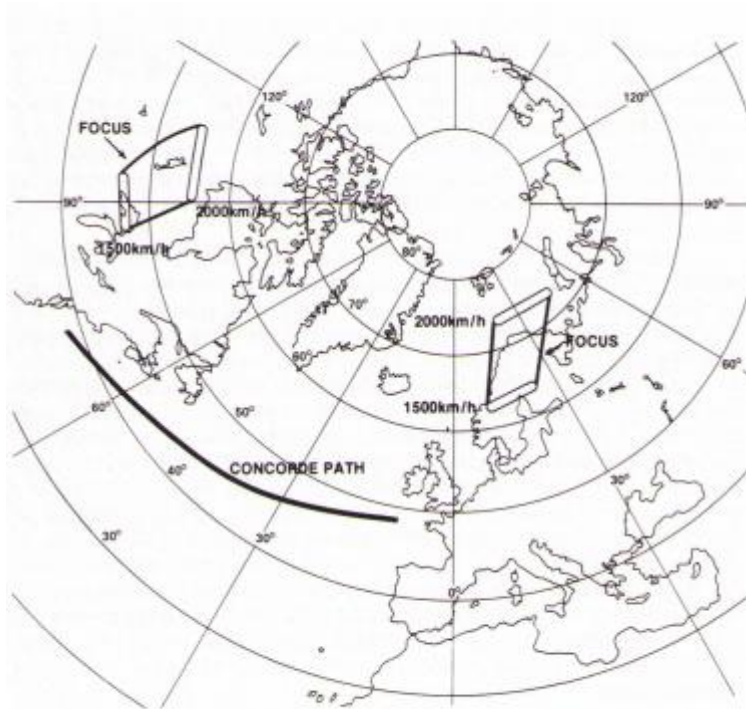


FIGURE 5<sup>34</sup>  
 AREAS IDENTIFIED AS POTENTIAL RECIPIENTS OF  
 LOW FREQUENCY WAVES - CONCORDE

Supersonic booms are not a new phenomenon, having been a fact of life since the first planes broke the sound barrier. To prevent inconvenience of populated areas during training flights, most supersonic maneuvers are conducted away from the coastline, although by law the planes need be only 5 km from the coast. In addition, Warning Areas are designated so that military maneuvers can take place without jeopardy to civilian aircraft. Figure 6 outlines these Warning Areas and shows the approximate distances.

Off the South Carolina coast, speeds above Mach 1 are routinely authorized 42 km from the coastline.<sup>36</sup> There are no known reports of citizen complaints about these flights prior to December 1977. On December 2, between 0900 and 1200, an F-14 was flying at Mach 1.6 in Warning Area 108 off the Delaware/Maryland region<sup>36</sup> but no booms were reported from these states. As noted by the NRL investigators, the actual times planes may be flying over Mach 1 speeds are unknown, as flights are not always monitored and records are not kept. The indication of such incidents is from pilots' acknowledgments that supersonic flights occur relatively close to land.

NRL reviewed only events which included both citizen observations and seismic and/or acoustic signal recordings. As the seismic and acoustic equipment at Weston and Lamont-Doherty respond only to low frequency signals, it is not possible from instrumented observation alone to determine whether high frequency or audible signals were also present. NRL claims that: "All observations are consistent with the conclusion that the events detected in both New Jersey and Charleston were infrasonic when they reached land."<sup>39</sup> The NRL report argues that the great majority of the booms were observed only by citizens inside a structure. The implicit hypothesis is that the low frequency components of the booms are converted to audible frequencies through resonant response of the structure.

The NRL study also notes flights at supersonic speeds toward VORTAC beacons in Charleston and Atlantic City.<sup>40</sup> Straight line flying would generate carpet booms which might explain the low frequency sound waves recorded at Lamont-Doherty, Weston and Baptist College.

In Tucson, Arizona, a very similar occurrence of booms, house and ground shaking caused general alarm during April 1975. Richard Wood at the U.S. Weather Service discovered that on days of particularly numerous reports, the jet stream's southwesterly\* winds were averaging 150 to 205 miles per hour (130 to 178 knots). On the days military supersonic flights were being conducted in Sills, Arizona,

\*Wind direction is given from point of measurement, a southwesterly flows from southwest to northeast.



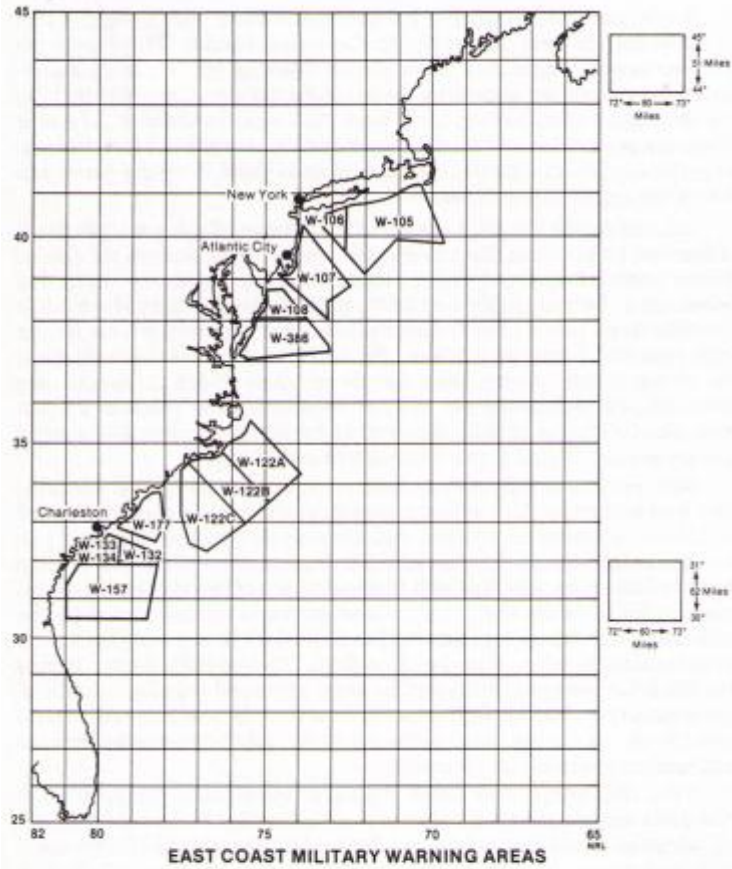


FIGURE 6<sup>37</sup>  
EAST COAST MILITARY WARNING AREAS

about 115 km west-southwest of Tucson, the high jet stream winds, associated strong vertical shear and temperature inversion over Sills--Tucson, may have focused the sonic booms into the Tucson area 115 km from the flight path.<sup>41</sup> Again, it is unclear but very probable that the jet plane maneuvers caused the initial focused booms, which were then carried through the atmosphere as far as Tucson without attenuation of the high frequency components.

It has been pointed out that weather conditions along the Atlantic coast on December 1, 1977, included winds on the order of 140 to 180 knots, with strong vertical shear and temperature inversion. During this period, the winds were again southwesterlies. If the Atlantic coast events were similar to those in Tucson, then the jet planes would have to have been 120 km inland over Delaware and southwest New Jersey, not 80 km out to sea.

William Donn of Lamont-Doherty examined daily January mean wind speeds and directions for these years to see if indeed unusual weather conditions existed along the Atlantic coast for 1978; his data are presented in Figure 7.<sup>42</sup> It is apparent that there is no obvious difference between the three years. Other tables of maximum jet stream wind speeds tend to confirm his observation. As discussed in the Wood article, where maximum winds reach 140 knots and over, many reports from Tucson citizens were received; when winds drop below 87 knots no reports were made of vibrations or sounds. A few calls were received when wind speeds were between 87 and 140 knots. The data base shows four days of coincidental observations (citizen and instrumented) for New Jersey, and ten days of coincidental observations in South Carolina. Table IV compares days of coincidental events and maximum recorded wind speeds in the region reporting these events.

There were several other days of maximum wind speeds over 150 knots in Charleston. On January 26, a 150 knot west-southwesterly was blowing and on February 11, a 163 knot northwesterly was recorded. No events were reported for either day. Similarly, in the New York area, maximum wind speeds over 140 knots are recorded on December 3, 4, and 5, and February 16, 17, 18 and 20. Two reports of sounds on December 3 were made at very early morning hours when no planes were aloft, all other days are without reported incidents.

Using ray tracing techniques, NRL determined from seismic and acoustic signals that the location of the source of certain of the New Jersey booms was at 39°30' N, 74°10' W. Referring to Figure 5, these coordinates are only 10 km off the coast of Beach Haven, New Jersey. The altitude of the source is estimated at 2500 meters.<sup>43</sup> At this altitude and horizontal distance, the direct carpet boom would certainly be audible along the coast. If planes operated supersonically so close to shore and at low altitudes, the question arises as to absence of reports

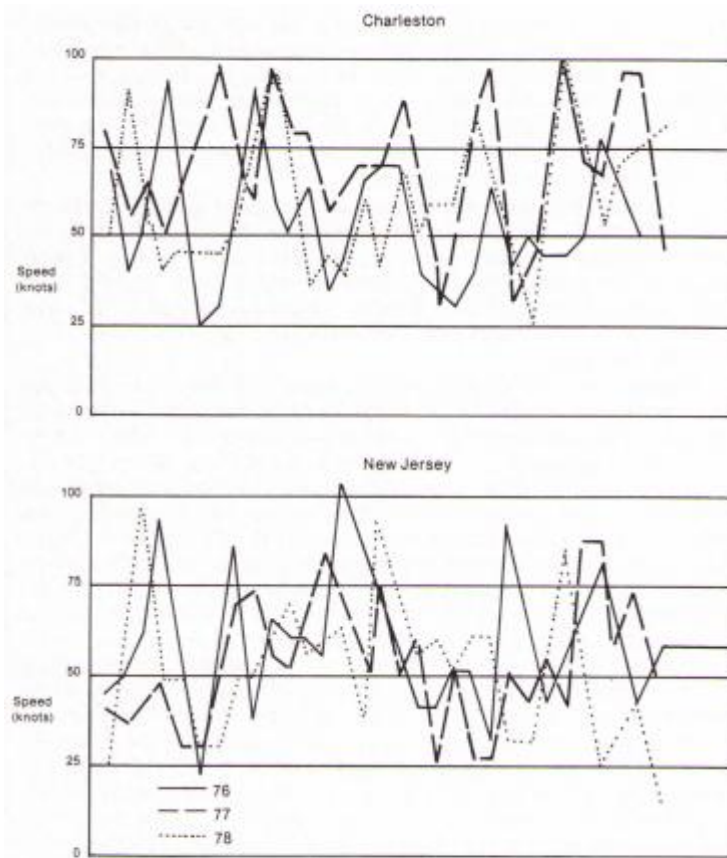


FIGURE 742  
 MAXIMUM WIND SPEEDS

TABLE IV  
COMPARISON OF EVENTS AND WIND CONDITIONS

		New Jersey		Charleston	
		Knots	Direction	Knots	Direction
December	2	170	SW	140*	SW
	15			110	N/A
	20			85	SW
	22	95	SW	80	SW
January	2	90	N/A		
	3			160**	W
	4	80	N/A	90	N/A
	5	65	N/A	70	N/A
	6			50	N/A
	11	70	NW		
	12			70	N/A
February	21			170***	SW

\* No planes aloft during one simultaneous event

\*\* No planes in Warning Areas directly off Charleston, plane in area NE of Charleston

\*\*\* Flights of military aircraft unknown

of damage. A further puzzle is why, in some 15 years of military aircraft maneuvers, were there not earlier reports of booms? Nine different events hit on December 2, and a total over a six-week period of 32, if all reports (when aircraft were operating in the Warning Areas) are attributed to supersonic flights.

Charleston data did not allow ray tracing, so actual areas of origin are unknown. Observers, however, say the sea, and this has been agreed upon as the direction from which the sounds came. December 2 was used by NRL as the basis for the flight/weather conclusion. Very strong southwesterlies were indeed blowing, but the interesting point about the Charleston analysis is that one of three coincidental events (seismic, signals and citizen) on December 2 occurred when NO planes were in the Warning Areas, as did the additional citizen observations on the same day. Of five events on December 2, only two can be explained by the operating military aircraft.

Three other days are considered to have had particularly intense events in Charleston; December 22, January 2 and February 21. Winds on December 22 had a maximum speed of 80 knots; on January 12, a

maximum of 70 knots; only on February 21 are the speeds again at 160 knots, but it is unknown whether any planes were operating. Two other days of coincidental events used by NRL to confirm the operational flight theory are December 20 and January 3. In both cases, the only Warning Area where any aircraft were flying is W177 northwest of Charleston. As seen on Figure 6, the nearest southern edge of this zone is about 50 km from Charleston. Maximum winds on December 20 were only 80 knots, insufficient for wind focusing. On January 3, very strong winds existed, over 160 knots, but these were westerlies.

In summary:

- All acoustic and seismic signals received by Lamont-Doherty, Weston and Baptist are considered by NRL to be infrasonic, without accompanying frequencies in the audible range, although observers describe sounds like blast, boom, cannon shot, as well as having felt vibrations.
- Ducting conditions would have propagated the infrasonic sounds with low transmission loss without focused booms, but the intensities reported suggest that focusing must have taken place during audible observations unless supersonic flights were being conducted only 10 km off the coastal areas.
- No particularly unusual weather conditions existed during January 1978, as compared to the same month for the previous two years.
- Over half the coincidental events occurred when wind speeds were under 90 knots, Richard Wood's cut-off for similar occurrences in the Tucson area involving military maneuvers and distance weather focusing.
- Several coincidental events occurred when no military aircraft were in coastal Warning Areas; December 2 and January 3 in Charleston; January 2 in New Jersey.
- A large number of events, acoustic/seismic signals and/or citizen observations, occurred when no aircraft were flying in the Warning Areas: 67 (30 acoustic only) of 99 events in New Jersey and 19 (3 seismic only) of 41 events in Charleston.
- The coincidence that many of the observations occur on weekdays between 0700 and 2200 is not sufficient reason to assume the causes are man-made, as these hours can be explained as normal times citizen observers are awake. In fact, of the eleven observations involving intense vibrations, some with loud booming sounds, felt in the Charleston region between January 25 and April 23, three of them are reported between 2400 and 0500 hours and two of the eleven are on Sunday.

## CONCORDE THEORY

In mid-March, Jeremy Stone of the Federation of American Scientists, suggested that the Concorde was responsible for the New Jersey and Charleston events as well as the Nova Scotia events.<sup>44</sup> He revised his conclusion in May indicating Concorde was responsible for the Nova Scotia events,<sup>45</sup> a conclusion reached earlier by NRL. Stone suggested that the New Jersey and Charleston events might be explained by long distance propagation through the hot upper atmosphere where the speed of sound reaches values twice the speed of sound at ground levels.

Garwin,<sup>46</sup> stimulated by Stone's speculation, analyzed the propagation of small amplitude, non-dissipating waves into the hot and tenuous high atmosphere. With his approximations, Garwin found that Concorde-generated shocks would significantly perturb the high atmosphere by heating and by causing strong winds. The heating could explain observation of lights. Further, the shock would propagate through the high atmosphere at an average velocity slightly less than the velocity of the aircraft at the point from which the shock was launched. Thus, the acoustic disturbance could travel through the atmosphere at a near velocity well above the velocity of sound at sea level. The booms refracted by the thermosphere, called hyperbooms by Garwin, could travel horizontally for hundreds or thousands of kilometers and through focusing could produce the observed east coast booms.

Gardner & Rogers<sup>47</sup> and MacDonald et al.<sup>48</sup> have shown that a weak shock launched in the lower atmosphere remains weak throughout its path. Since the shock loses 90 percent of its energy before reaching 100 km, the shock will neither heat the high atmosphere nor cause measurable winds. Furthermore, on reaching the ground after refraction in the high atmosphere, the sound wave will be too weak to be observed audibly.

The carpet boom, from a fighter jet, can be heard at 40 to 50 km from the flight path. A Concorde-generated carpet boom may reach 80 km from the flight path. Ribner has calculated a cut-off point on the distance a Concorde focused boom (a boom from acceleration, turning, or deceleration) to be very similar to a carpet boom, that is 80 to 90 km from the points of origin.<sup>49</sup> Gardner & Rogers have determined that a sonic boom traveling in the thermosphere will reach the ground at a horizontal distance of about 320 km from the point it left the aircraft but with a very low amplitude.<sup>50</sup>

In addition, Gardner & Rogers have also found that: "Sound received along the flight-track is a minimum. The largest (low frequency approximate .1 Hz) signals occur 200 to 400 kms from the flight track."<sup>51</sup> This is in agreement with the observations of Grover.

Atmospheric ducting conditions have also been considered for long distance wave propagation. However, the high speed upper atmospheric winds prevailing on several days of east coast events are opposite in direction to the sound waves, that is, blowing from southwest toward the northeast, whereas sound waves are generated in the northeast.

If the sound waves were produced on the approach toward New Jersey as the airplane is decelerating, the Concorde would arrive 13 minutes ahead of the first thermosphere boom. Gardner & Rogers have found that there are no likely reasons that the boom would proceed the decelerating aircraft. It is also the case that a decelerating plane produces a weaker shockwave than an accelerating plane.

As pointed out in the NRL study, many of the Nova Scotia events correlate very clearly with passage of Concorde flights.<sup>52</sup>Detailed analysis of the more than four hundred events from Nova Scotia show that 56 percent of the events are within thirty minutes of the calculated flight time for Concorde. Thirty-five percent of the Concorde related events result from arriving planes and 65 percent from departures. It is not clear why the departures account for the larger fraction, as the flight path calls for a distance of 180 km off the shore, whereas the arrivals are closer at 80 km. Rates of aircraft acceleration and climb are possible explanations. The observations are in rough agreement of weaker shockwave generation by decelerating planes, with more intense shockwave generation by accelerating and climbing planes. There remain 21 events in Charleston, and 67 events (30 acoustic only) in New Jersey which cannot be explained by military aircraft, as well as 93 events in Nova Scotia unrelated to Concorde. There are also 13 observations of unexplained light phenomena in New Jersey, which brings the total of unexplained events to 194 incidents.

## REGIONAL INVESTIGATION

Rattling homes and unexplained booming noises are not new to areas along the Atlantic seaboard. As noted in the first section and Appendix II, such sounds have been commonly heard around the world. There are also many reports of light phenomena in the sky unrelated to thunderstorm or lightning, and of flames from the water, such as: "Fire-Ship of Bay Chaleur," New Brunswick, investigated by the famous Canadian Naturalist, W.F. Ganong;<sup>53</sup> the Summerville, South Carolina, light;<sup>54</sup> an unusual illumination of the sky seen from Sandy Hook, New Jersey;<sup>55</sup> and the strange lights of Gardiner's Bay, New York.<sup>56</sup> Certain of the noise and light phenomena currently observed may be reoccurrences of the same historically noted events.

NRL reviewed some historical data and were convinced of a major difference between current and past events, namely that the past events were observed by persons outside, whereas most of the current events are observed by persons indoors.<sup>57</sup> This is only partially true, as some historical events are observed inside, and some current accounts are reported outside. One should also remember that a majority of people 100-150 years ago worked outside more often than inside. The NRL Study also noted that most historical events occurred during calm, warm days. Again, certain current events were indeed reported on calm, warm days, as some were reported at midnight in winter with winds blowing. The inference from the investigation by NRL is that all events were infrasonic--that is, below audible; but reports cite booming noises, blasts, explosions or rumbles.

"Eyewitnesses (in Charleston) describe a variety of phenomena, but they agree that there is sound offshore--sometimes shattering loud blasts, sometimes thunderlike growling noises."<sup>58</sup> "A mysterious shaking sensation, coupled with sounds of explosions in some areas, frightened thousands of residents in four New Jersey coastal counties Friday afternoon."<sup>59</sup> The descriptions of blasts and explosions are inconsistent with the hypothesis that the audible sounds resulted from the excitation of vibrations in the buildings by infrasonic waves.

### COMPARATIVE STATISTICS

#### Charleston

Fifty-four events occurred in the Charleston, South Carolina, region between December 1, 1977, and May 3, 1978. Figure 8 shows the reporting areas. Three additional events are noted in the NRL Study as being observed seismically but not heard; these three observations have not been confirmed by Baptist College. Of the fifty-four events, thirty-six occurred during the period studied by NRL: December 2 through January 12. Ten of the thirty-six were reported by



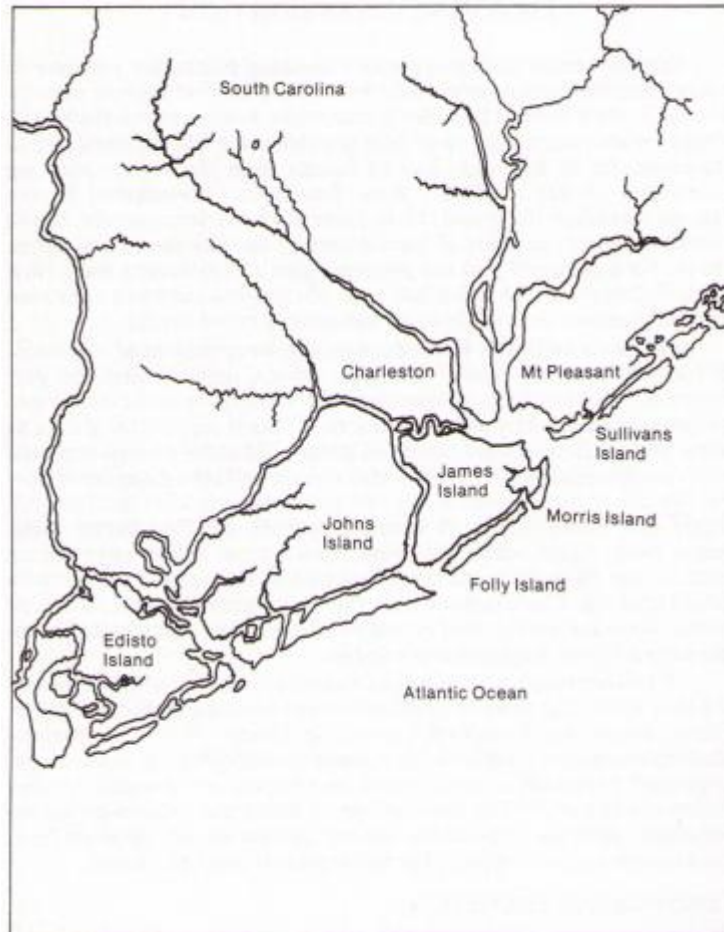


FIGURE 8<sup>61</sup>  
CHARLESTON, SOUTH CAROLINA AND VICINITY

citizens and recorded as atmospheric disturbances by the Baptist College seismic net.

The NRL report states that *all* of the coincidental (citizen and seismic) events occur during military operations.<sup>60</sup> However, two of the ten events were at times when military aircraft were not flying in Warning Areas W132, 133/34 or 157. Another eleven observed events were noted at times when military operations were not being conducted. Therefore, 36 percent of all reported events cannot be explained by reported supersonic aircraft operations.

After January 12, fifteen more events were observed. The most severe to date was February 21. Four booms were observed from Sullivan Island to Summerville, as well as recorded on the Baptist College seismic array. It is not known whether military operations were being conducted on the morning of February 21. Very strong upper southwest winds were blowing on this day. Other events which occurred after the NRL investigation, are reported at 0400, 0500, 2100 and 2400. Because military flights are normally conducted after 0800 and cease by early evening, these events are not considered the result of military operations. Table V presents a time distribution of all unexplainable Charleston events.

Table V illustrates the time of day, day of week correlation noted in the NRL report. In all but three cases (0710, 0715, 2100) supersonic aircraft can be excluded; the nineteen events were reported over a period of 21 weeks; and 50 percent of these observations are before 0800 (8:00 A.M.) or after 2000 (8:00 P.M.). Simple coincidence cannot be ruled out. A historical parallel is the series of shocks experienced in Charleston after the August 1886 earthquake. "For nearly two months . . . no Friday or Tuesday passed during this period without a shock of greater force than those which occurred on other days . . . Friday indeed came to be known throughout the state as earthquake day."<sup>62</sup> Six small earth tremors also occurred in Charleston during the period December 1977, through May 1978; all on weekdays, but these did not have, as far as can be determined, a cultural origin.

#### New Jersey

Noise, lights, vibration, acoustic and seismic signals, and a combination of noise and light phenomena were reported in New Jersey during December 1977, and January 1978. Figure 9 identifies the various towns and types of phenomena reported. The NRL Study investigated the period from December 2, 1977, through January 14, 1978; this study includes observations through January 26, 1978. The summary tables do not include the June 30, 1978, event at Ramapo, in which an explosion was reported by citizens seconds before they felt the shock of an earthquake of magnitude 3 on the Richter scale.

TABLE V  
DISTRIBUTION OF UNEXPLAINED CHARLESTON EVENTS

SUN	MON	TUE	WED	THU	FRI	SAT
		0145 0400**	0500** 0715**		0710** 0830	
(0930)	0800 0930	0856 (0930) 1100	(0930)	1125	1130*	
		1355 1453*	2100**	2130 2145	1600	
2400**						

\* Observed and recorded on the Baptist College seismic net  
 \*\*Events before or after availability of data on military aircraft operating in Warning Areas  
 ( ) Acoustic signals only - from NRL study unconfirmed by Joyce Bagwell of Baptist College  
 \_ Coincidental events

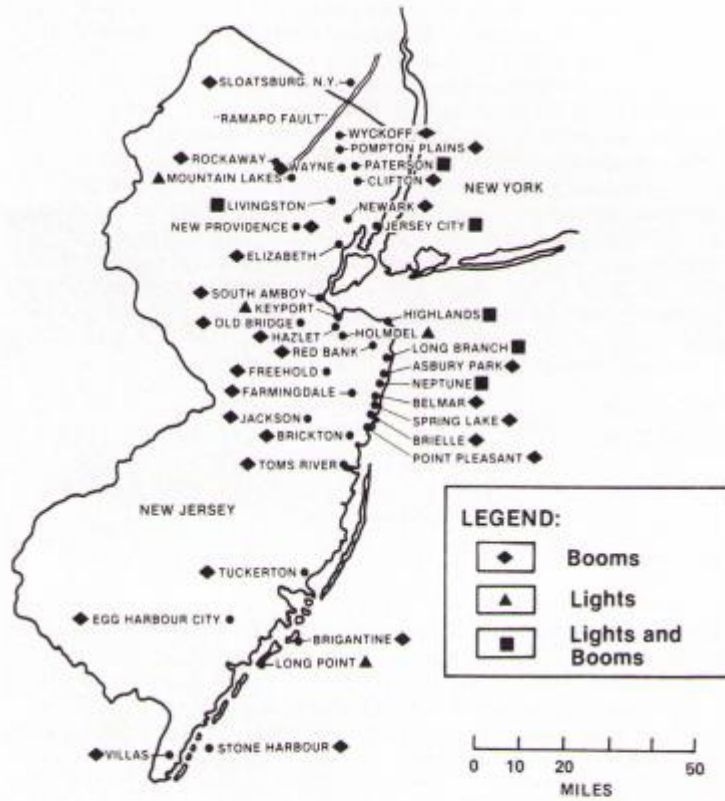


FIGURE 9  
LIGHT & SOUND PHENOMENA IN NEW JERSEY

One hundred and one different events are noted in Appendix IV. NRL reviewed six events on December 2 and 22, 1977; January 4 and 11, 1978.<sup>63</sup> The NRL actual times of two of the six events reported could not be confirmed, namely, January 4 and 11, although several events did occur on these days at times not recorded by NRL. The imprecision of observation times complicated attempts to correlate seismic or acoustic signals with citizen reports. If a fifteen minute difference between a citizen report and instrumental recording is allowed, then seven events were reported by citizens and recorded instrumentally. Of the seven, five were during times at which supersonic jets were flying in the Warning Areas, two at times when supersonic jets were not in the air. Twenty-five additional observations (twelve acoustic or seismic reports only), were also made at times military planes were operating in the Areas. Sixty-seven other events appear to be unrelated to military operations. These include:

<u>Instrumented Observations</u>	<u>Citizen Observed</u>	<u>Lights Only</u>	<u>Lights and Booms</u>	<u>Vibrations Only</u>
27	19	13	5	1

Coincidental Citizen and Instrumented Observation

2

Table VI shows the time distribution for instrumented observations and for all other observations. There is a very marked difference between the two, suggesting different origins. All but two of the acoustic seismic-detected events occur during the week between 0752 and 1800, mostly on Wednesday and Thursday. The other events are distributed over the week with the majority occurring before 0800 or after 1800. Citizen reports, a total of forty, do not show a culturally oriented time distribution. Of the nineteen booming phenomena reported, seven are between 0000 and 0530; and five occur on Saturday.

Historical booming noises are not known in the New Jersey area, but light events have been reported. One particular example is called the Phantom Brakeman. However, documentation is scarce, although at least two non-profit private groups (Vestigia, Inc., and NICAP) have investigated these observations.

**Nova Scotia - Shelburne County**

In the late Nineteenth Century a fascinating compilation of reports on sounds heard along the New Brunswick/Nova Scotia, Bay of Fundy coastline was published by Samuel Kain and others, including W.F. Ganong.<sup>64</sup> Ganong had heard the sounds himself, and had given a paper to the New Brunswick Natural History Society in 1896.<sup>65</sup> Descriptions

**TABLE VI  
DISTRIBUTION OF UNEXPLAINED EVENTS - NEW JERSEY**

ACOUSTIC/SEISMIC ONLY					ALL OTHERS						
*Mon	Tue	Wed	Thu	Fri	Sun	Mon	Tue	Wed	Thu	Fri	Sat
					0000-0100 <sup>1</sup> 0030-0103 <sup>1</sup>			0100-0130 <sup>2</sup>			0100
						0200 <sup>1</sup>		0200 <sup>1</sup>	0132		0200-0300 0237
								0340			0345
										0530	
									0600 <sup>2</sup>		
									0700 <sup>1</sup> 0730 <sup>1</sup>		
									0830 <sup>2</sup>		
	0838 0757	0804-0812 0854 0906-0912 0938 0956 1018 1128	0752-0809 0847-0850 0900 0924-0925 1001			1030-1130		0915	0900-1000	0900 0915 0920	
1141	1137		1153	1209			1215				
			1330-1355					1245-1300		1330	
			1418-1428 1457						1404	1400 <sup>2</sup>	1430-1530 (5b)
		1710	1546-1548 1725								
			1800		1800-1830 <sup>1</sup>						
	1903	1959					1845 <sup>1</sup>	1900 1900 <sup>1</sup>			
								2000-2100 <sup>1</sup>			
							2100-2200 <sup>1,2</sup> 2225 <sup>2</sup>	2200-2400 <sup>2</sup>	2200-2400 <sup>2</sup>		
								2300 <sup>1</sup>			

<sup>1</sup> Lights only  
<sup>2</sup> Lights & Boom  
<sup>3</sup> Vibrations only

\*No Acoustic/Seismic Observed On Sunday  
— Coincidental Observation (Instrument and Citizen)

in these articles include: "distant firings of heavy guns," "a rattle of a 24-pounder cannon exploded 40 feet from the buildings," and "guns from porpoise fishermen." The times and places where the noises (known as airquakes, sea farts or booms) were heard vary considerably within the articles. They are observed in January, February, "only in calm, warm weather," "early spring mornings," "never at nighttime," at 0200, 2100 and 2300 (specific examples), outside, inside, and 40 miles from land in a boat. One writer swears they are subterranean, while Ganong says there is nothing subterranean about the ones he heard.

We find today the same sort of variations in observations that have been historically noted. The following examples of descriptions, times and places of current events are from the record logs of the Barrington Energy Awareness Center.<sup>68</sup> Reports of booms, not related to Concorde, have occurred at 0100, 0550, 1145 and 2304. They are described as similar to: "a clap of thunder," "a blast of dynamite," "gunshots," and "a loud bang, without rumble or vibration." In one incident, both the husband and wife heard the noise, although the wife was on land and the husband was out on the water. Most observers do agree that the noise is more likely coming from the air, although a woman observer who lived in Laurentians, Quebec, believes the sounds she is hearing in Northeast Point are exactly like the ground noises during the Quebec earthquakes. Her first report of noises correlated with Concorde, but the second did not. These events have been continuous since January.

Reading over the hundreds of observations, we are struck by the fact that most of the incidents which do not correlate to Concorde are described as bangs or booms without vibrations. This, however, is really inconclusive, although many observers are becoming increasingly discriminating in their descriptions.

The almost five hundred events (over one thousand observations) reported to the Energy Awareness Center provides the most complete observation data base in this study. There is no acoustic or seismic equipment in the region to record infrasonic signals as has been the case in Charleston and New Jersey. Figure 10 shows some of the reporting villages in Shelburne County.

There is little doubt that sonic carpet booms from the British/French Concorde are responsible for over 50 percent of the events being heard and felt in Nova Scotia. The flight path passes near Nova Scotia while the aircraft is still at supersonic speeds or just reaching supersonic speed. In this report, interest centers on the 50 percent of the events that are probably not directly due to Concorde.

Information regarding Canadian military operations near southwestern Nova Scotia is unavailable. Reports by some Concorde

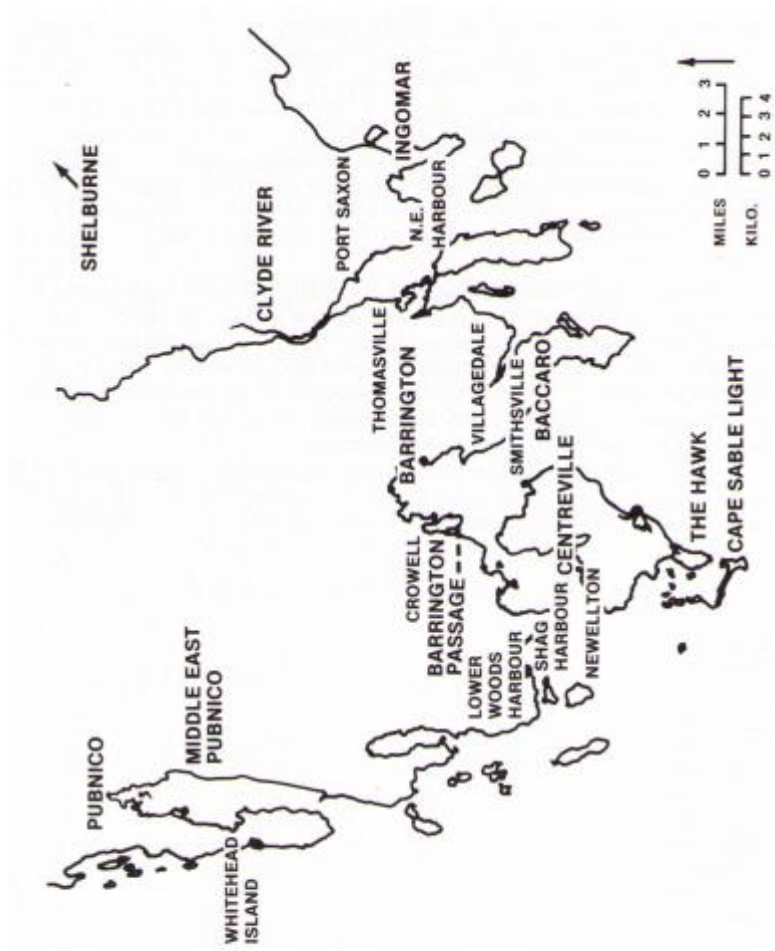


FIGURE 10<sup>67</sup>  
 SOUTHWESTERN NOVA SCOTIA  
 SHELBURNE COUNTY



pilots<sup>68</sup> of seeing jets near the flight path suggest that on occasion Canadian fighter pilots may be using the Concorde as a model for the Soviet supersonic bomber, the Backfire.

All the Nova Scotia events have been classified as either correlated to Concorde (within 15 minutes before or after the SST has passed), associated (within 30 minutes before or after the SST has passed), or non-associated (more than 30 minutes before or after the SST has passed). All events which include a double boom as part of the description are also classified as associated, no matter what time they were observed.

There is an inherent problem in the classification; that is, events considered as associated may, in fact, be completely unrelated to aircraft flights. Because of this, non-associated events may have been classified as associated. The same is true of double booms; whatever is causing the Nova Scotia non-Concorde sounds may generate one, two or many distinguishable booms. Reports of three, four, or more booms have not been automatically categorized as associated.

Of the 436 events from January through May 1978: 243 (56 percent) correlate to Concorde; 100 (23 percent) are considered associated; and 93 (21 percent) are non-associated. Tables VII and VIII

TABLE VII  
NOVA SCOTIA — NON-ASSOCIATED EVENTS

2201-2400					1		
2001-2200				3		1	
1801-2000	2	1	1			2	6
1601-1800	3	2				1	4
1401-1600	3	1	1	4	1	4	2
1201-1400	6	1		2	1	2	5
1001-1200	3	3	1	1		7	1
0801-1000	1	1	3	3	1		1
0601-0800		2	2				2
0401-0600		1					
0201-0400							
0000-0200					1		
	Sun	Mon	Tue	Wed	Thu	Fri	Sat

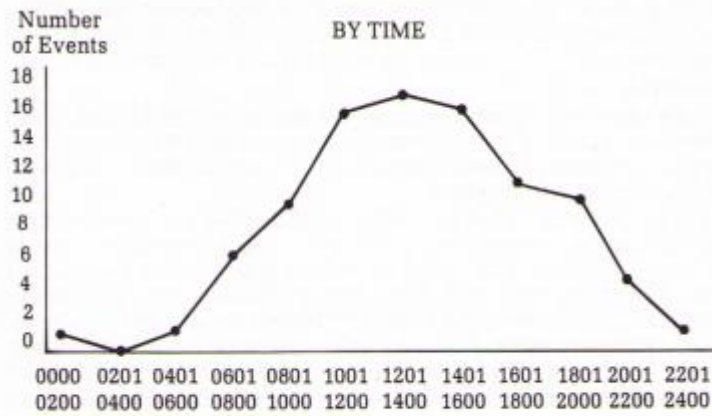
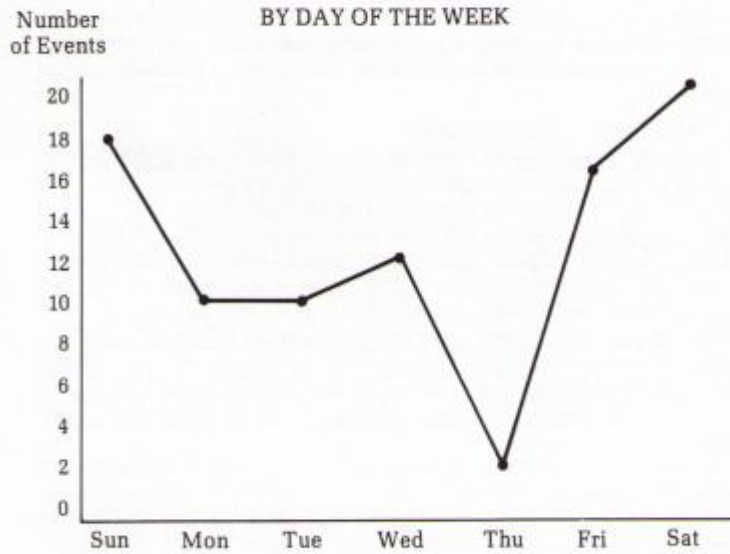
Concorde Flights - 4-6 Flights per day average

4 to/from JFK daily

2 to/from Dulles Mon, Thu, Fri, Sat, Sun

1 to/from Dulles Tue, Wed

TABLE VIII  
DISTRIBUTION OF NON-ASSOCIATED EVENTS



represent distribution of time, day of the week, and number of non-associated events observed.

Attempts to correlate non-associated events using hourly ground wind speeds and surface temperature do not produce an obvious pattern, although when wind speeds are over 40 km per hour, no events are reported. Similarly, no events are reported during heavy snow fall. Most observations occurred when wind speeds were under 24k/h (15 m/h). The weather-boom correlations are listed at the end of Appendix VI.

#### Other Areas with Noise Phenomena

Tuesday, December 20, 1977, three loud explosions accompanied by a ball of fire were reported by residents of New Canaan, Connecticut, at 2343.<sup>69</sup> There were no military aircraft in the area, nor any apparent man-made explosion in the town or surrounding region. A canister labeled as Signal Illumination Ground White Star Parachute was found in the vicinity of the reports, but no conclusion was reached by the investigators as to its possible connection with the event.

New Canaan is near the town of East Haddam, known many years ago for the famous "Moodus Noises." These sounds are described as loud booms like artillery, but normally are accompanied by shaking and rattling of homes. There are no known historical references to light flashes.

Members of the National Weather Service, police officers, and citizens of Tidewater, Virginia, were surprised by a 20-second tremor, which shook houses and according to one observer, "sounded like someone dropped two tons of bricks from the third floor,"<sup>70</sup> March 31, 1978. A seismograph of Tidewater Community picked up signals, but the operator did not know whether it was an earthquake or not. Officials at the National Earthquake Center in Colorado are also unsure. Both sonic booms and two 15-gun salutes from the carrier *John F. Kennedy* were ruled out as causes. It has remained undetermined exactly what happened at 1132.

Citizens have reported unusual sounds in parts of Canada, other than Nova Scotia. The two principal areas are in Ontario: Cornwall, located southeast of Ottawa along the St. Lawrence Straits, and Burlington, located near Hamilton.

The Cornwall "Thumps" began on December 26, 1977, with the last documented report January 15, 1978, causing some alarm among the local residents. The series of thumps occurring, for example, at 0100, 0300, 0500, 1040, 1205, 2000, 2110, are described as "someone or something hitting the side of a wall."<sup>71</sup> Several theories have been proposed, such as a reoccurrence of noises heard before the 1944 earthquake, or ice cracking on roof tops, suggested by the investigating seismology team.<sup>72</sup> No recordings were picked up on a seismograph in-

stalled in Cornwall for a week, and the ice theory has not been substantiated.

On Sunday, March 5, 1978, at 1822, in Cornwall, a loud boom rattled windows and knocked articles off the shelf. A small earth tremor Richter Scale 2.3, was picked up by a New York seismology station.<sup>73</sup> What is perplexing to Canadian seismologists is that tremors below Richter Scale 3 are rarely felt above ground, nor do such loud noises generally accompany such small tremors. A shock was also experienced by residents at 0833 January 9, the same day thumps were reported in Cornwall. Earlier reports of a booming noise similar to the March 5 incident were made by residents on June 30, 1975. The blasts seem to most observers to be coming from the ground. Similar observations have been reported in Burlington.

Reviewing the hundreds of current and historical reports, it is apparent that unusual noise phenomena are heard in many places and by many people. Over the years, numerous explanations have been suggested. With the advent of SSTs, reports of booms have become more numerous in certain places. Familiarity with supersonic booms may lead to a decrease in citizen interest in reporting events, some of which may be of natural origin. Numerous other man-made explanations have been put forward, even extremely strong low-frequency radio waves. However, an examination of the kind carried out by NRL can be used to dispose of the man-caused alternative. It is far more likely that natural causes are responsible for many of the current observations as they are for many of the historical ones.

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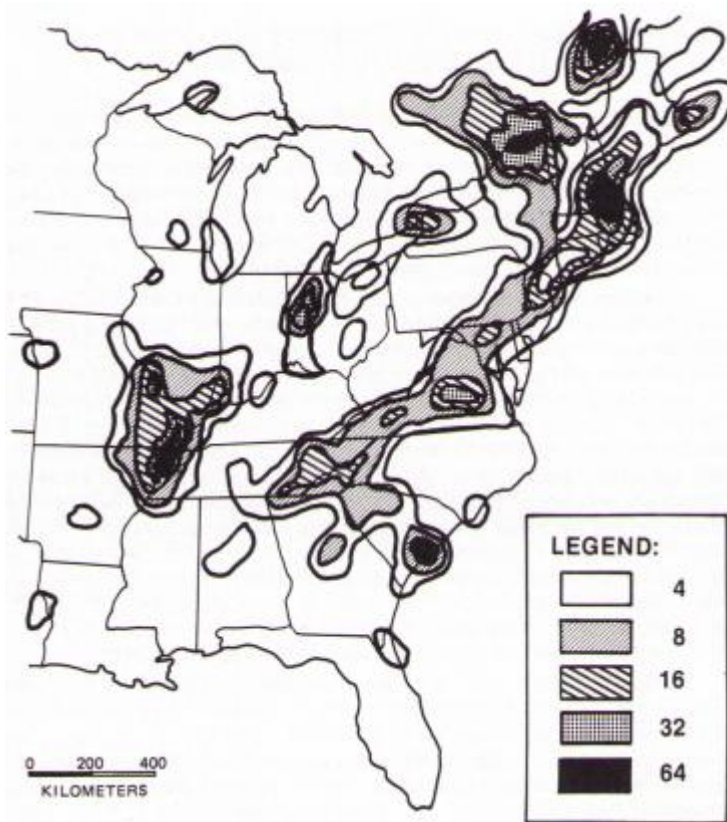
## NATURAL CAUSES OF CURRENT AND HISTORICAL LIGHT AND SOUND PHENOMENA

The diverse nature of the booming phenomena heard along the Atlantic Coast and in the Canadian provinces of Ontario and Nova Scotia indicate that several mechanisms may have produced the booms. Numerous historical accounts, provided by Nineteenth Century naturalists, suggest that natural events may cause booms. Despite the rich literature describing the booms, few hypotheses have been put forward to explain booms in terms of natural events.

Since certain of the booms have been noted at or near the time of the earthquakes, the suggestion has been made that the actual ground motion associated with an earthquake generates an acoustic signal. The intensity of the sound wave will be proportional to the square of the magnitude of the ground displacement coupling to the atmosphere. The initial ground shock (seismic P wave) almost always has a very small amplitude, and could not generate the observed booms unless, in the epicentral region, the disturbance triggered landslides or mass movement of unconsolidated sediments. Seismic disturbances are characterized by much lower frequencies than the audible part of the spectrum so that the generation of sounds heard outside buildings by a ground disturbance is an unlikely event. Further, booms are known to have been observed prior to the actual ground shaking, yet the velocity of sound in the atmosphere is almost always distinctly less than the velocity of propagation of a disturbance in the underlying rock.

Gold and Soter<sup>74</sup> have suggested that release of combustible gases along a break or pre-existing fault in the crust could be responsible for the booms if the gases ignited or exploded. Gold and Soter argue that flames or lights seen along the ground trace of the fault in some earthquakes are evidence of combustible gases, presumably methane. NRL examined venting methane as a possible cause for the booms. Their conclusion suggests that the volume required for ignition and subsequent explosion would be difficult to generate in a single bubble because of rapid dispersion in the atmosphere and the large quantities required.<sup>75</sup> Alternatively, the release of high pressure methane or non-combustible gases could result in a boom or an explosive sound without any associated flash or explosion.

Large areas of the earth's crust are considered aseismic. Even in these more stable regions, earthquakes and booms can occur. The severe 1976 earthquake in Anatolia, Turkey, was in a region considered aseismic, since no earthquakes had been noted for at least three generations.<sup>76</sup> The populace of Charleston were unfamiliar with earthquakes prior to the 1886 event. The east coast of the United States, while tectonically inactive relative to California, does contain regions considered to be of high seismic risk (See Figure 11).



The Numbers Indicate Seismic Frequency Measured by the Total Number of Earthquake Epicenters of MM III and Greater per 10,000 Square Kilometers During the Years 1800-1972.

FIGURE 11<sup>77</sup>  
SEISMOTECTONIC MAP OF THE EASTERN UNITED STATES

### Charleston and Vicinity

On August 28, 1886,\* an article entitled the "Summerville Sensation" appeared in the *Charleston News and Courier*, describing an earthquake shock felt the previous day in Summerville, about 20 miles from Charleston. "Some of the people from Summerville . . . said that a rumbling sound was first heard in a northwesterly direction from the town, and that the sound was followed by an explosion resembling that of a cannon at a distance."<sup>78</sup> The citizens of Charleston greeted this pronouncement of an earthquake "as another one of the alleged miracles and phenomena of the pineland Munhausen."<sup>79</sup> That was until the following day, August 28, when another tremor hit the Summerville area but was also unmistakably felt in Charleston. On this day, four shocks were perceived in Summerville itself, at 0410, 1320, 1457, and 1630. The first was considered by the observers as the most severe. Rumbling sounds were heard between 0400 and 0500 in Mt. Pleasant, but residents of Sullivan Island (See Figure 8) heard and felt nothing. Slight shocks were also felt at about 0400 in Augusta and around 0500 in Wilmington, North Carolina.<sup>80</sup> The significance of the coincidental swarm of earthquakes in Summerville, Charleston, Augusta and Wilmington was recognized only recently with the renewed study of MM IX-X\*\* earthquake epicenter and surrounding areas.<sup>81</sup>

After the major earthquake of August 31, 1886, continued aftershocks were felt, but as reported in the *Yearbook*, there were other strange phenomena: "Certain peculiar disturbances at Charleston . . . were frequently observed . . . these disturbances consisted of single heavy 'thumps' . . . they produce no perceptible motion of buildings, nor of suspended or loose objects in buildings, and so far as known, were noticed only by observers *within doors*."<sup>82</sup>

Although the 1886 earthquakes seemingly surprised the South Carolinians, a few earthquakes had been previously reported in this region. Table IX is the known earthquake history of the area beginning as far back as 1799.<sup>83</sup> There has been an increase in seismic activity since 1959. Thirteen earthquakes over MM III have been reported for the Summerville-Charleston region since the last of the 1886 series (November - MM VII Summerville). Ten of these thirteen have been recorded since 1959.

Tectonically, the Charleston-Summerville area does not have obvious surface faults. Recent work has defined affected areas correlating direction and damage from historical records. Looking at seven major North American earthquake centers, all show correlations

\*Erroneously printed as August 27 in the 1886 Charleston *Yearbook*.

\*\*MM = Modified Mercalli Scale - See Appendix I for definition of intensity numbers.



TABLE IX<sup>83</sup>  
 HISTORICAL EARTHQUAKES  
 REGION OF CHARLESTON

DATE	MM	PLACE
APR 1799	V	Charleston
JAN 1817	IV	Charleston
DEC 1857	V	Charleston/Savannah
JAN 1860	V	Charleston
JAN-AUG 1886	V<	20 Earthquakes
AUG 1886	IX-X	Charleston-Columbia/Augusta-Savannah
OCT 1886	VI-VII	Charleston
NOV 1886	VII	Summerville
JAN 1903	IV-VI	Tybee Isl., Ga.-Charleston
APR 1907	V	Charleston-Augusta
JUN 1912	VI-VII	Summerville-Charleston
SEP 1914	IV-V	Summerville-Charleston
DEC 1933	IV-V	Summerville
AUG 1959	VI	Summerville/Charleston
MAR 1960	V	Off Coast of Charleston
JUL 1960	V	Vicinity of Charleston
OCT 1967	V	Summerville/Charleston
OCT-NOV 1974	IV	3 MM IV Charleston Area
NOV 1974	VI	Charleston/Summerville
APR 1975	IV	Charleston
JAN 1977	V	Summerville

with magnetic anomalies "presumably caused by extensive mafic and ultramafic embedded in the crystalline basement."<sup>84</sup> In Charleston, the eastern portion of the epicenter is bordered by "large, circular magnetic and gravitational 'high' which appear unique" for the eastern coastal plain.<sup>85</sup>

#### New Jersey and Vicinity

The Ramapo Fault, considered by many seismologists as an old and inactive fault, has begun to show signs of movement. Twelve tremors in the last two years: " 'until recently we did not know for sure where earthquakes occurred in this part of the world, primarily because there were no instruments. Even six months back we didn't know exactly where these shocks came from. We are now associating some of the shocks with known faults.' Including Dr. Aggarwal (head of a team of seismologists at Lamont-Doherty) says the Ramapo."<sup>86</sup>

The most interesting aspect of the Ramapo is the close correlation between events seen and heard during December 1977, and January 1978, and the recent epicenters of localized earthquakes in the same area. The fault line, epicenters and phenomena of 1977/78 are shown in Figure 12. There have been a number of earthquakes in New Jersey, New York and Delaware. A list of the more important earthquakes is presented in Table X.

One of the most severe earthquakes to occur in New Jersey was on June 1, 1927, near Asbury Park, with a magnitude of MM VII. Recent geologic work has shown some magnetic anomalies and a transcurrent trend extending southwest from the Kelvin Seamounts and crossing New Jersey about midway along the coast. Figure 13 shows this trend with areas reporting booms and lights noted near the area. As no obvious surface fault exists between Asbury Park and Tom's River, this trend/fault may help explain the earthquake activity in this region.

#### Nova Scotia

In October 1869, a MM VIII earthquake occurred in the Bay of Fundy, causing damage to structures between Fredericton and St. John, New Brunswick. A second large earthquake, MM VII, occurred on March 21, 1904. The epicenter was in southeastern Maine (Calais and Eastport) but it was felt in Nova Scotia and New Brunswick. Nova Scotia was not badly affected again until November 1929, when the MM IX earthquake, centered off Grand Banks, Newfoundland, caused heavy damage particularly from a resulting tsunami. A list of historical earthquakes is presented in Table XI.

There are several known fault lines in the Bay of Fundy, as shown in Figure 14, but less is known of the southeastern tip of Nova Scotia. The areas particularly subjected to current noise phenomena are all on the opposite side of Nova Scotia, facing the Atlantic and near the area identified in historical literature as an area where boatmen heard sounds when out at sea.

Only one earthquake seems related to sounds. In a report from a naturalist to W.F. Ganong in December 1895, the author recalled hearing noises "more the resonance from the falling of a heavy body into the water than the firing of a gun"<sup>90</sup> near Passamaquoddy Bay. A small earthquake, MM IV-V, occurred in Calais, Maine, close to Passamaquoddy Bay in March 1896. No additional reports of sounds from the Bay are known after this date.

The current sounds are exclusively reported from the tip of Nova Scotia facing the Atlantic, not the Bay of Fundy. The locations of the reports vary, although all are along the seaboard and most observers note the direction as "from the sea."

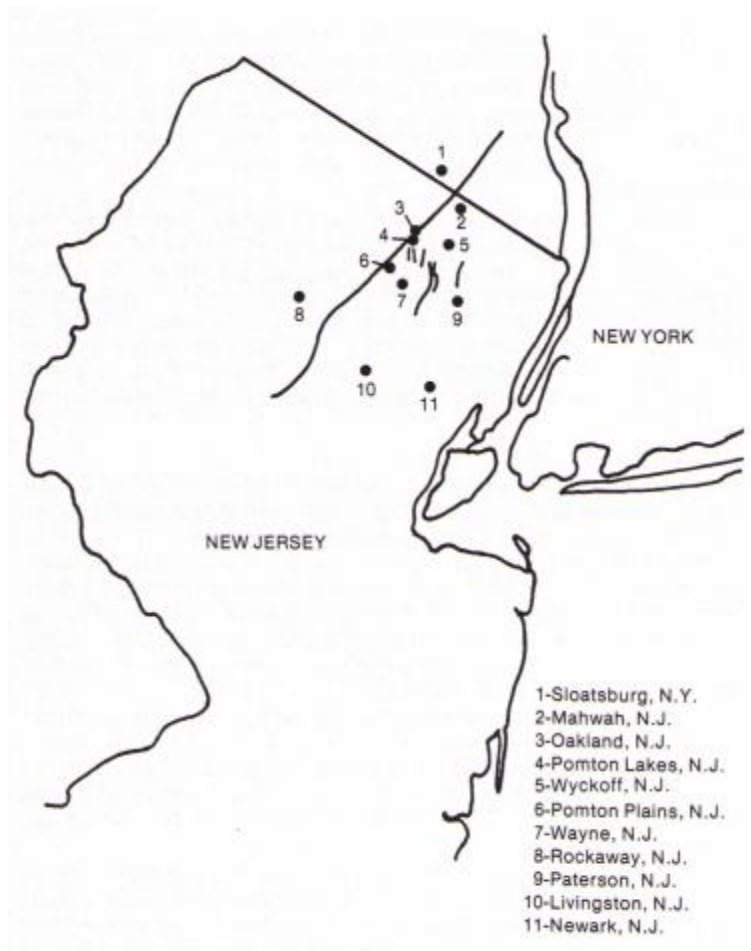


FIGURE 12<sup>87</sup>  
 CORRELATION OF THE RAMAPO FAULT AND  
 NEW JERSEY EVENTS

TABLE X<sup>88</sup>  
 HISTORICAL EARTHQUAKES  
 SOUTHERN NEW YORK, NEW JERSEY, DELAWARE

DATE	MM	PLACE
OCT 1871	VII	Wilmington, Del.
DEC 1874	VI	Westchester Co/Nyack/Tarrytown, N.Y.
DEC 1875	VII +	Baltimore, Md. - Greensboro, N.C.
OCT 1878	V	Hudson River/Peekskill, N.Y.
AUG 1884	VII	Near New York City
MAR 1893	V	New York City
SEP 1895	VI	W. of Newark, N.J.
MAY 1906	V	Seaford, Del.
JUN 1916	V	New York City
MAY 1926	V	New Rochelle, N.Y.
JUN 1927	VII	Asbury Park, N.J.
JAN 1933	V	Near Trenton, N.J.
NOV 1939	V	Salem Co., N.J.
SEP 1951	V	Rockland, N.Y. - Dover, N.J.
OCT 1952	V	Poughkeepsie, N.Y.
MAR 1955	VI	W. Central New Jersey
NOV 1964	V	Westchester Co., N.J.
NOV 1967	V	Westchester Co., N.J.
DEC 1968	V	Southern New Jersey
FEB 1973	V	W. New Jersey
JUL 1973	IV	Delaware/New Jersey
APR 1974	V	Wilmington, Del.
JUN 1974	VI	Wappinger Falls, N.Y.
MAR 1976	IV	Pompton Lakes, N.J.
APR 1976	V	Ridgefield, N.J.
AUG 1976	IV	White Plains, N.Y.
NOV 1977		7 small earthquakes near Ramapo Fault
JUN 1978	IV	Mahwah - Oakland, N.J.

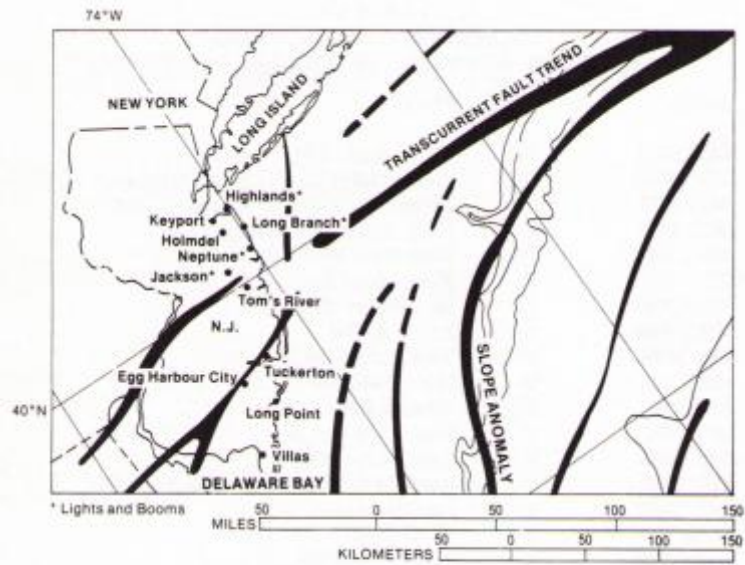


FIGURE 13<sup>99</sup>  
 HIGH INTENSITY MAGNETIC TRENDS  
 ALONG THE ATLANTIC CONTINENTAL SHELF

TABLE XI<sup>91</sup>  
 HISTORICAL EARTHQUAKES  
 MAINE COAST, NEW BRUNSWICK, AND NOVA SCOTIA

DATE	MM	PLACE
1855	VI	Monton-Dorchester, N.B.
OCT 1869	VIII	Bay of Fundy
FEB 1874	V	Bangor-Eastport, Me.
JAN 1881	IV-V	Bath/Brunswick, Me.
DEC 1882	V	Rockland/Bangor/Eastport, Me. - Halifax, N.S.
MAR 1896	IV-V	Calais, Me.
SEP 1898	IV-V	Belfast, Me.
MAR 1904	VII	Calais/Eastport, Me. - St. Stephen, N.B. - Yarmouth, N.S.
JAN 1910	V	Cumberland Co., Me.
DEC 1912	V-VI	Augusta, Me. - Fredericton, N.B.
JAN 1914	V	Calais, Me. - St. Stephen, N.B.
AUG 1918	VII	Bridgton - Cape Elizabeth, Me.
NOV 1929	IX	Grand Banks, Newfoundland
APR 1957	VI	Off Coast Near Portland, Me.
SEP 1958	V	Cape Elizabeth
JUL 1966	V	Jonesport, Me.

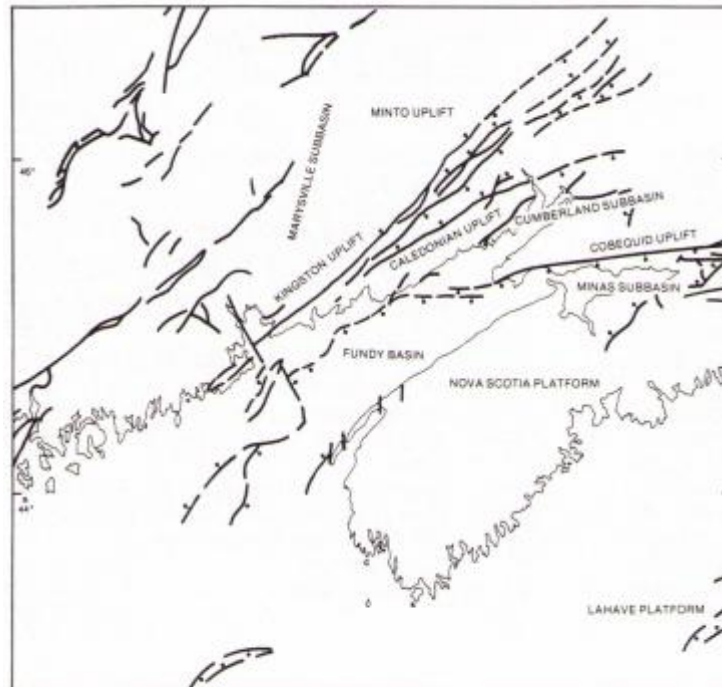


FIGURE 14<sup>92</sup>  
NOVA SCOTIA—BAY OF FUNDY FAULT LINES

### Booms and Earthquakes

The locations of the recent booms not associated with aircraft operations coincide in a general way with areas of historical earthquake activity. Few booms have been reported from areas for which few historical earthquakes have been reported (See Figure 11). While the correlation is suggestive, the evidence from historical accounts is mixed, since booms have been reported in areas having no seismic activity and in areas of much more intense earthquake activity. For example, in California reports of booms exist but are relatively infrequent. Even if booms are associated with tectonic disturbances, the mechanism is not clear. It is highly unlikely that the minor ground displacements associated with a small earthquake such as the Ramapo could yield an explosive sound. Gold and Soter proposed that the release of combustible gases could lead to the observed sounds. Similarly, the high- pressured release of gases could produce sounds.

The relatively recent discovery of numerous gas seeps in the Gulf of Mexico where they can be detected by sonar is suggestive that leaks of gas from below may be a more common phenomena than has been previously reported.<sup>93</sup> Gas seeps over land or over water not being investigated with sonar could easily go undetected unless special observations were made with the goal of attempting to detect the earth's outgassing. Unlike oil seeps, gas leaks into the atmosphere have no trace unless ignition takes place and flames or an explosion are observed or if the release is at sufficiently high pressure to cause a boom. The outflowing gas could originate in old organic deposits (conventional gas) or could have a non-conventional, non-organic origin deep within the earth. We are currently studying the latter possibility and its implications for estimates of natural gas recoverable resources.



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## CONCLUSIONS AND RECOMMENDATIONS

Many of the "East Coast Mystery Booms" can be attributed to artificial sounds, mostly supersonic aircraft. There remains a large residual, about one-third of all reported events, that cannot be accounted for easily. The number of unexplained events, the locations of reports of events, the timing of events and abundant historical accounts of similar events all indicate a natural origin. In certain cases, for example the Ramapo earthquake sequence, the reported booms are clearly associated with a natural event. While we cannot prove that there were 181 natural booms on the east coast during a six month period, we find the evidence strong for a natural origin of many of them. With currently available evidence we cannot go much beyond this conclusion other than to point out that the identification of the source of the natural booms could have far-reaching consequences in such disparate areas as atmospheric physics, earthquake prediction, and energy resources estimation.

It is not difficult to understand why the booms were labeled as mysterious or that scant scientific attention has been paid to them, as the observation of natural phenomena which received much attention in the Eighteenth and Nineteenth Centuries is no longer fashionable. In the case of noise phenomena, the heightened artificial noise levels and the widespread awareness of powerful man-made noise sounds has undoubtedly dampened interest in the study of natural noise. The official pronouncement of the U.S. Government, the NRL report, that the 1977-1978 booms could easily be understood certainly did not encourage further interest in the problem by the public, the press, or the scientific community.

The irony of the present situation is emphasized by the calls for greater research efforts in the field by such great scientists as George Darwin eighty years ago. Ganong proposed in 1896 a questionnaire calling for a variety of observations, including the nature of the sounds, location of observation, wind direction and velocity, state of the sea and sky. "It is very desirable, since the sounds occur here, that they be scientifically observed and recorded; and it is best to communicate the results to this society, through which they will reach those who can make best use of them."<sup>94</sup>

Kain, in his summary article of 1898, encouraged continuing research. "Instead of accepting any hypothetical explanation as satisfactory, it is best, at the present stage of the investigation, to keep one's mind free from prejudice in any special direction. It seems quite possible that the noises proceeding from the ocean may have very different characters and origins . . . It is highly probable that a careful collation of observations from many stations . . . will throw a clear

light upon the locality whence the noises emanate.<sup>1195</sup>

The lack of adequate observational facilities to study atmospheric acoustical phenomena further hindered the analysis of the east coast booms. In the United States, atmospheric acoustics received considerable attention in the 1950s and 1960s, first because of an interest in detecting nuclear explosions in the atmosphere and second because of concern over the effects of flying supersonic transports both American and Concorde. More recently, atmospheric acoustics have been largely neglected. At the start of the east coast events there was only one low-frequency acoustic array in operation, the Lamont-Doherty facility.<sup>96</sup> At Lamont, Donn operates two tripartite arrays of capacitor microphones. During March and April, 1978, in order to supplement existing observational facilities, MITRE operated three two-microphone correlators at Bedford, Massachusetts; Atlantic City, New Jersey; and McLean, Virginia. The analysis of the east coast booms was aided by the existence of several seismic arrays in which atmospheric pressure disturbances are recorded along the vertical axis. However, seismometers cannot approach the performance of modern acoustic instrumentation.

The work of the Lamont, Kiruna<sup>97</sup> and Sibizmir<sup>98</sup> shows that large numbers of artificial sounds can be detected at large distances. The number of artificial sounds and their intensity suggest that a number of properties of the atmosphere such as thermospheric conditions can be studied using netted acoustic arrays. Such arrays having desirable directional properties could be used in identifying and describing natural sound sources.

We recommend the construction and operation of several multimicrophone (100 or so microphones) to observe both natural and man-made sounds over a broad frequency band. Such arrays are essential to the determination of background noise levels and the identification of natural and artificial events. The extremely low attenuation (0.001 db/km at 1 Hz) makes possible the identification of events at great distances. Depending on the nature of the sounds, the array could be designed to have highly directional properties.

The identification of artificial sounds will require a determination of the source spectra. Little is known of the sounds spectra of possible major artificial sounds such as large-scale explosions, aircraft, and pile-drivers, nor is much known about the excitation of large structures such as bridges in a way to generate low-frequency noise. Because of the strong dependence of the attenuation on frequency, sounds observed at substantial distances will have their energy in the infrasonic portion of the spectrum.

The systematic reporting of unusual noise events by citizens has proved very useful in investigating the east coast booms. The en-

couragement of reporting of such events together with a means of analyzing the reports could provide a useful adjunct to instrumented observations.

As we have documented, unusual noises have been reported for centuries. Their origin remains as mysterious as when Darwin called for further research. The existence of inexpensive capacitor microphones, the great computer capabilities in data processing and analysis, the enhanced understanding of sound propagation in the atmosphere all indicate that much could now be done to clear up the centuries-old mystery.

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## APPENDIX I

### MODIFIED MERCALLI SCALE DEFINITION

Modified Mercalli Intensity Scale of 1931, abridged from H. Wood and F. Neumann, *Bulletin of the Seismological Society of America*, Vol. 21, No. 4, pages 277-283, December 1931.

#### SCALE

- I Not felt except by a very few under specially favorable circumstances.
- II Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.
- III Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motorcars may rock slightly. Vibrations like passing of truck. Duration estimated.
- IV During the day, felt indoors by many, outdoors by few. At night, some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like heavy truck striking buildings. Standing motorcars rock noticeably.
- V Felt by nearly everyone, many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop.
- VI Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.
- VII Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motorcars.
- VIII Damage slight in specially designed structures; considerable in ordinary substantial buildings, with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving motorcars disturbed.
- IX Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; damage great in substantial buildings, with partial collapse. Buildings

- shifted off foundations. Ground cracked conspicuously. Underground pipes broken.
- X Some well-built wooden structures destroyed; most masonry and frame structures destroyed with their foundations; ground badly cracked. Rails bent, landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks.
- XI Few, if any (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and landslips in soft ground. Rails bent greatly.
- XII Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into air.

## APPENDIX II

### ACCOUNTS OF SOUNDS AND LIGHTS

Phenomena associated with earthquakes have been studied for centuries. Aristotle suggests that winds "also produce those noises underground which are heard before earthquakes. And in some places subterranean noises are heard unaccompanied by earthquakes . . ."99 In 1571 eleven signs or precursors to earthquakes were identified including: Stillness of the air, unusual conduct of animals, muddiness of wells, motions and swelling or odors from the sea without wind, appearance of columns of smoke or of exhalations in the air, and various sounds in the earth and air.<sup>100</sup> Many of these events have been re-discovered in recent years in connection with earthquake prediction studies.

References to unusual phenomena are numerous from the Eighteenth and Nineteenth Centuries, but much less frequent in the Twentieth. On the following pages are many examples of recorded noises, sounds and related phenomena taken from journals, newspapers, and books. A bibliography of some major collections is found at the end of this Appendix.

Some historical sound phenomena are consistently reported by different observers, allowing easy categorization of them. In other cases, observers have recorded different types of phenomena in the same region which may preclude easy categorization of the sounds.

The four major noise categories are:

1. Noises without earthquakes or other associated natural events, occurring in areas seismically inactive;
2. noises observed irregularly over many years in an area of occasional seismic activity but seemingly unrelated to the noise;
3. noises which occur at least one hour prior to an earthquake; and
4. noises accompanying or momentarily preceding an earthquake.

#### NOISES WITHOUT EARTHQUAKES OR OTHER ASSOCIATED NATURAL EVENTS OCCURRING IN AREAS SEISMICALLY INACTIVE

Darwin, G.H.; *Nature*, 52-650, October 31, 1895

In the delta of the Ganges, dull sounds, more or less resembling distant artillery, are often heard. These are called "Barisal guns"; but I do not know the meaning of the term. The object of this note is to draw the attention of the readers of *Nature* to this mysterious phenomenon, and to the similar "mist pouffers" of the Belgian coast.



My attention was for the first time drawn to the subject some days ago by a letter from M. Van den Broeck, Conservator of the Museum of Natural History of Belgium. He writes of certain "curious aerial or subterranean detonations," which are pretty commonly heard, at least, in Belgium and in the north of France, and which are doubtless a general phenomenon, although little known, because most people wrongly imagine it to be the sound of distant artillery.

"The detonations are dull and distant, and are repeated a dozen times or more at irregular intervals. They are usually heard in the day-time when the sky is clear, and especially towards evening after a very hot day. The noise does not at all resemble artillery, blasting in mines, or the growling of distant thunder."

Before any systematic observations are undertaken, it will be useful to form some general idea of the frequency of these sounds and of their geographical distribution.

Will any of the numerous readers of *Nature* in various parts of the world give us an account of their experiences in this matter?

Ponton, Mungo; *Earthquakes, Their History, Phenomena and Probable Causes*, T. Nelson & Sons, Edinburgh, 1888, page 215.

It has occasionally happened that loud and long-continued subterranean noises have been heard, without their having been accompanied either by earthquake shocks or any other outward indications of internal disturbance. One of the most remarkable examples of this kind occurred at Guanaxuato in Mexico, and is described by Humboldt in his *Cosmos*. This city is situated in a mountainous district, but far from any active volcano. The sounds were first heard at midnight, on the 9th of January 1784, and they continued more than a month. The loudest reports occurred from the 13th to the 16th of January 1784, when they seemed like slow rolling thunder, with intervening short thunderclaps. Both before and after this period the sounds were neither so loud nor so frequent, and after the 16th they gradually died away. No shocks of earthquake were felt, nor did any other consequences follow. What is still more remarkable, in the neighboring mines, which are 1598 feet deep, not the slightest trembling of the ground was perceived.

Cooper, W.S.; *Scientific American*, 75:123, August 1, 1896

On the evening of December 28, 1885, I was with a companion in a sailboat on the Gulf of Mexico about 20 miles S.E. of Cedar Keys, Florida. We were becalmed. The next morning the sky was cloudless. There was a light fog and no breeze. The atmosphere was bracing but not frosty. We were about ten miles out but in

shallow water. Shortly after sunrise we heard reports as of a gun or distant cannon. They came at intervals of about five minutes. We were not certain as to the direction. My companion, who lived several miles further down the coast, said he had often heard the reports on still mornings.

Smith, W.S.; *Nature*, 53:197-198, January 2, 1896

Lough Neagh is a sheet of water covering an area of upwards of 150 square miles. For many years after my settlement as minister here from England, I heard at intervals, when near the lake, cannon-like sounds. I passively concluded that the reports proceeded from quarrying operations, or, on fine summer days, from festive gatherings in Co. Derry, or Co. Tyrone. In time I came to understand that it was not from the opposite shores, but from the lake itself that the sounds proceeded. After questioning many of the local residents, I extended my inquiries to the fisherman, but they could assign no cause. A strange thing about the matter is that the people generally knew nothing of the phenomenon, and that it is shrouded in mystery. I have heard the reports probably twenty times during the present year, the last being on a Sunday afternoon a month since, when I heard two explosions, but with two exceptions they have all seemed to come from many miles away, from different directions at different times. I have as yet spoken to no one who observed any movement of the waters when explosions took place, nor have I spoken to any one who was close to the spot at the time. Rather everyone seems to have heard them only in the distance, which is strange, as fishermen are on the lake during many months in the year, at all hours of the day and night.

Robinson, Charles H.; *Nature*, 53-487, March 26, 1896

In 1810 a party, outfitted by John Jacob Astor, made an overland trip from the Missouri to the mouth of the Columbia. They tried to go through the Black Hills, but were obliged to withdraw and flank them. In these hills they note as follows: "In the most calm and serene weather, and at all times of the day or night, successive reports are now and then heard among mountains, resembling the discharge of several pieces of artillery." Similar reports were heard by Messrs. Lewis and Clark in the Rocky Mountains.

On July 4, 1808, we find the following entry in their journal: "Since our arrival at the Falls we have repeatedly heard a strange noise coming from the mountains in a direction a little to the north of west. It is heard at different periods of the day and night, sometimes when the air is perfectly still and without a cloud, and consists of one stroke only, or five or six discharges in quick succession. It is loud, and resembles precisely the sound of a six

pound piece of ordnance at the distance of three miles."

. . . The mountains towards which these noises were heard were the main range of the Rockies, and distant about eighty miles. In 1854, Mr. Doty, of Governor Stevens's party, heard similar noises. He was near enough to the mountains to be certain that the noises came from them. The locality where Mr. Doty heard them was where the direction observed by Lewis and Clark would strike the mountains.

Plenty of White men have been in this country for the last thirty years, or since 1866. I have made careful inquiry among pioneers, but cannot learn that the noises have been heard since Mr. Doty's report.

Personal Communication from Dr. J. Ling, 1978

Students studying late at night recall hearing loud dull booming sounds from Lake Cayuga, Ithaca, New York. The sounds occurred as single explosions, on windless winter nights. Cornell scientists have discussed the noises for years, but no specific explanation has been found.

Johnston, M.S.: *Geneva Gazette*, circa 1940

The "Lake Gun" . . . is an uncanny, mysterious sound, like the report of a far-away cannon, softened by coming over the water . . .

There has been a tendency to treat the whole subject in a skeptical manner. But scientists do not treat it so. They have regarded the lake gun of Seneca Lake as a perfectly respectable fact . . . that it was not a product of imagination . . . Dr. Hamilton L. Smith, for many years professor of science in Hobart College at Geneva . . . is remembered to have stated his opinion that the sound came from the explosion of gas collected in the bottom of the lake or in fissures of the underlying rock. This theory was practically demonstrated by the experience of a reliable neighbor who was startled and his canoe nearly overturned by a great bubble which came to the surface in the middle of the lake and burst with a loud noise.

The sound is usually heard on hot, sultry days, though one has heard the ice crack as Dr. Clarke suggests. More often than not they are heard on afternoons by the lake or on it, when the south wind was dying down or had ceased to blow, and the surface of the water had become glassy, or "oily" . . . and the sky has gradually become overcast with the haze of a gathering thunderstorm. Again out of the stillness one can hear coming from the south or southeast the solemn, lazy, deep-toned muffled, unexpected, "Boom!"

NOTE: Although much of New York has at one time or another experienced earthquakes, the Finger Lakes district seems to be free from seismic activity. There exist fault lines in this area but they are considered inactive.

**NOISES OBSERVED IRREGULARLY OVER MANY YEARS IN AN AREA OF OCCASIONAL SEISMIC ACTIVITY**

Ganong, W.F.; Upon Remarkable Sounds Like Gun Reports Heard Upon Our Southern Coast, *Bulletin of Natural History Society, New Brunswick*. (1897) p. 40

Everybody who has been much upon our Charlotte County coast must remember that upon the still summer days when the heat hovers upon the ocean, what seem to be gun or even cannon reports are heard at intervals coming from seaward. The residents always say in answer to one's question: "Indians shooting porpoise off Grand Manan." This explanation I never believed; the sound of a gun report could not come so far, and besides the noise is of too deep and booming a character . . . .

The discussion upon the subject by this Society on December 3rd, 1895, has called out further information showing that others besides myself have noticed these or similar sounds in New Brunswick . . . .

The latest opinion as to the origin of the sounds appears to favor an atmospheric origin . . . . It is very desirable since the sounds occur here, that they should be scientifically observed and recorded; and it will be best to communicate the results to this Society, through which they will reach those who can make the best use of them. To secure the best results the following form, altered somewhat from M. Van den Broeck's circular, should be followed.

Name of observer.

Date of observation.

Exact place of observation.

Exact time of each observation.

Direction of the sound.

Character of the sound (full description with comparisons).

Wind, direction and velocity.

State of the sky.

State of the sea.

Mist conditions.

Barometer (state of the weather a few hours before and after).

Temperature.

Other remarks, including suggestions as to their origin, and reasons why they cannot be gun reports.

Kain, Samuel W., et al.; *Monthly Weather Review*, 26:152-154,  
April 1898

It gives me much pleasure to send you by this mail a copy of Professor Ganong's article. I am also sending you two short notes from lighthouse keepers at the mouth of the Bay of Fundy. Mr. McLaughlin is at the southern end of Grand Manan; Mr. Suthern is on Brier Island, on the Nova Scotian shore.

I wrote to these men in order to get some more information about this phenomenon. I have also personally questioned masters of fishing schooners, all of whom are familiar with these sounds, and among whom they are known by the somewhat vulgar but very expressive name of "sea farts." I am sending you these papers because I think these sounds very similar to those discussed in Europe about two years ago by Van den Broeck, Darwin, and others. A reference to them in the *Review* may elicit more information than we now have.

Walter B. McLaughlin, of Grand Manan, on remarkable sounds like gun reports, etc. (read March 1, 1898, before the Natural History Society of New Brunswick, and now quoted from the *St. Croix Courier*): I had just caught my first mackerel when "boom" went this heavy sound and away went our fine school of fish . . . I inquired the cause of these sounds so frequently made and the sailor's answer was: "We don't know, we hear them, but we can't explain them."

The first one of these sounds I heard under Gannet Rock was about fifty years ago, one clear, dark night, about 2 o'clock a.m., in my watch. I was reading and was deeply interested, when bang went the shock of what seemed to be like a 24-pounder cannon. It brought down the soot from a heavy, boiler iron, extension pipe on the chimney top into an open fireplace. I, of course, went outside to investigate and found a clear, dark night with few clouds and light winds. It was, I think, in October.

My next experience of one of those sharp shocks was in the month of June, 1856, at South Lubec, West Quoddy Bay. I . . . was having a game at cards with the doctor about 2 o'clock in the morning, when bang went one of those subterranean guns, which nearly upset our lamp. I exclaimed, "An earthquake!" but the doctor said, "No; it's an airquake," an explanation I never heard before nor since till I read it in the *Bulletin of the Natural History Society*.

My third experience of those shocks on solid ground was at Seal Cove about eight years ago, say at 11 o'clock in the evening, when the shock was exactly as the former ones, the night being quiet and dark with very light winds. Again on the 28th of January of this year (1897) at 9 o'clock in the evening we got such a shock

under this lighthouse that we thought the tops of our chimneys had gone by the board. On the evening of February 14, at 9 p.m., we received another shock, but not so violent as that of January.

I have given you my experience of fifty-nine years, and I will now affirm that I strongly believe these sounds are of subterranean origin.

E.W. Suthern, from a letter to Mr. Kain, dated April 15, 1898, at Westport Light, Brier Island, Digby County, N.S.:

I have noticed these sounds many times when I have been out on the Bay of Fundy on fine, calm days in the summer. The sounds heard in this place are like the distant firing of heavy guns. I have heard these sounds on all sides of my boat . . . between my boat and the shore when one-half mile off shore, and again I have heard them in the same direction, 10 miles off. I have also heard them in a southwesterly direction, and there is no land within 300 miles southwest of here.

NOTE: Major earthquake occurred in the Bay of Fundy October 22, 1869, Modified Mercalli Scale (MM) VIII, with a smaller one in December 1882, MM V and a MM VII in March 1904. The area was also affected by the Grand Banks of Newfoundland earthquake November 18, 1929, MM IX.

Davis, W.M.: *Science*, December 3, 1897, pages 834-835

A correspondent of the New York *Sun* states that the "famous and mysterious disturbances of the lower Connecticut Valley, the 'Moodus noises,' are being heard again after a silence of twelve years. For twenty years, up to 1729, the villagers thereabouts heard the noises almost continually 'shaking the houses and all there is in them.' " They were heard again in 1852 and 1885. On the recent occurrence there was a sound like a clap of thunder, followed for some two hours by a roar like the echoes of a distant cataract. A day later there was a crashing sound like heavy muffled thunder and a roar not unlike the wind in a tempest. The ground was shaken . . . as though in an earthquake.

NOTE: A series of earthquakes occurred in East Haddam, Connecticut, from May 1791 (MM VIII) to August 1805. During the years 1876 to 1907 no earthquakes of MM IV or greater were reported in the State.

Golde, K.W.: *The Fortean*, October 1941, page 7

(From the Buffalo *Evening News* of March 2, 1940)

The mysterious "Moodus noises" have returned. At irregular intervals since colonial days, this region (Connecticut) has been shaken by sharp earth shocks and dull booming sounds have

echoed throughout the country side. No one has been able to explain them and even the Indians were mystified.

They thought the place so peculiar, they gave it its name meaning "the place of strange noises." Shortly before midnight the noises came back. Loud rumblings were heard and houses trembled. Townspeople were awakened. There was no damage. Scientists for years have been endeavoring to explain the cause of the noises which last were heard eight years ago . . . .

Anonymous; "The Deerfield (N.H.) Phenomenon," *Scientific American*, Vol. 2, 1846, page 2

We have frequently heard of singular and unaccountable reports, as of explosion, in Deerfield, but nothing so definite as the following statement by a correspondent of the *Portsmouth Journal*.

"Mr. Editor.--During the last twelve years, certain curious, not to say alarming phenomena in the town of Deerfield, N.H., have excited the fears of the inhabitants, and we think should, ere this, have attracted the attention of the scientific. These are reports or explosions in the ground, apparently of a volcanic or gaseous nature. When first heard they were attributed to the blasting of rocks in Manchester . . . it was soon concluded that they had some other origin. The explosions, if they may be so called, commenced on a ridge of land running S.E. and N.W. some five miles in length, and principally on that portion called the South Road. They have, however, extended, and are now heard in a northerly direction. The sounds have become louder, and during the last fall and the present spring or summer, as many as twenty have been heard in one night. Many of them jar the houses and ground perceptibly, so much so, that a child whose balance is not steady, will roll from one side to the other. They are as loud as a heavy cannon fired near the house, with no reverberation."

NOTE: The earliest known earthquake in this region near Pawtuckway, occurred in August 1810 at Exeter, N.H., MM VI. Two earthquakes MM V-VI took place in Southern N.H. on November 1884 and May 1891. Only two reported earthquakes had epicenters near Deerfield, these were the Manchester, N.H. quakes in March 1926, MM VI and October 1966, MM V.

Hawkins, B.C.; "Seismic Noises in North Carolina and Georgia," *Monthly Weather Review*, September 1897, pages 393-394

Mention has been made in the *Monthly Weather Review* of certain sounds heard on Black Mountain, N.C., in 1876, and obviously caused by the slow falling or sliding and crushing of rocks. But I am going to describe a phenomenon which seems to be very similar to the famed "barisal guns," and located right in the

United States. No account of these sounds has ever been published, and no scientist has ever taken the slightest interest in them, or paid any attention to them, so far as the writer knows.

In northern Georgia, in the extreme north of Rabun County, close to the North Carolina State line and thirty-fifth parallel of latitude, is Rabun Bald Mountain, forming one of the highest peaks on the very crest of the Blue Ridge . . . .

Now, on this mountain are heard mysterious sounds resembling distant cannon firing, and these sounds have been heard for many years, probably at least fifty; they have been heard in all kinds of weather and at various points on the mountain.

Numerous observers have noted the sounds, and two reliable gentlemen once spent a night on the summit. About 10 o'clock p.m., sounds were heard which were supposed to be cannon firing in Walhalla, S.C., in celebration of the presidential election, this being in November, 1884; but soon the sounds were found to issue from the ground and from a ridge to the southwest of the mountain. The explosive sounds continued till late in the night. At times they seemed to proceed from the ground immediately under the observers . . . . Some have heard these sounds so near them in the woods that the sound was like that of a falling tree. But ordinarily the sound is like distant firing, as noted above. They are not heard at all times, people having spent the night on the peak and heard nothing. The writer can verify all the statements made above. They are strictly true, and it is with the hope of calling the attention of scientific men to the subject that I present this brief account of the mystery of a mountain.

NOTE: Although no earthquake epicenters have been reported on the mountain, the area is seismically active.

The *News and Courier*, Charleston, South Carolina, October 11, 1886, front page

Excerpts from interviews of residents at Ninety-Six by reporters from the *Charleston News and Courier*.

"These noises have been going on for two years. Sometimes we would hear them three or four times a day, and then there would be none for a week or so. Then they would come again and then perhaps a month would pass before we would notice them once more. They resemble the falling of an old tree."

Mr. Hamilton reported that the rumbling last night (October 9, 1886) was more continuous than he had ever known . . . the second seemed as loud as the report of a gun a mile or two away.

Mr. Hill told the journalist "I heard the sounds night before last . . . it was like distant thunder or cannonading. It shook my house



and rattled the windows . . . this was the first time I had heard it since the (Charleston 1886, MM IX) earthquake."

NOTE: No earthquake epicenters have been recorded in the Ninety-Six area. From report excerpts, Charleston-Summerville earthquakes seem to affect the region although 150 miles away. The nearest epicenter was the Union County earthquake. January 1913, MM VII.

Rohleder, Herbert P.T.; *Geographical Journal*, January 1936, pages 61-62

. . . An old saying among the inhabitants around the lake is "Bosumtwi has fired or exploded gunpowder" (Bosumtwi oto atuduru). At irregular intervals once or twice a year, but apparently not within recent years, the lake becomes rough for one or two days, the colour of the water changes to almost black, the surface is covered with dead and dying fish, and the atmosphere becomes full of a choking smell of "gunpowder." The phenomenon is accompanied by a loud detonation. No rumblings or earth tremors are noted.

Although these periodic upheavals of the lake bottom might give rise to minor local explosions, it is impossible that these small detonations should be heard far away from the lake as has been reported frequently.

NOTE: Earth tremors were experienced in the region by geologists studying the area, however, the sounds seem to be unrelated to the movement. Like the Guns of Seneca, escaping gas was postulated as a possible cause.

Scott, G.B.; *Nature*, January 2, 1896, page 197

I first heard the Barisal Guns in December 1871, on my way to Assam from Calcutta through the Sunderbans. The weather was clear and calm, no sign of any storms. All day the noises on board the steamer prevented other sounds from being heard; but when all was silent at night, and we were moored in one or the other of the narrow channels, then at intervals, irregularly, would be heard the dull muffled boom as of distant cannon. Sometimes a single report, at others two, three or more in succession, never near, always distant, but not always equally distant. Sometimes the reports would resemble cannon from two rather widely separated opposing forces, at others from different directions but apparently always from the southward, that is seaward. We were not very far from the sea when I first heard them, and on mentioning to an old lady on board that I heard distant cannon, she first told me of the mysterious sounds known as the "Barisal Guns" . . .

I specially remember spending a quiet Sunday, in the month of

May, at Chilmari. About 10 a.m. in the day, weather clear and calm, we were walking quietly up and down near the riverbank, discussing the sounds, when we heard the booming distinctly, about as loud as heavy cannon would sound on a quiet day about ten miles off, down the river. Shortly after we heard a heavy boom very much nearer, still south. Suddenly we heard two quick successive reports, more like horse-pistol or musket (not rifle) shots close by. I thought they sounded in the air about 150 yards due west of us over the water. My friend thought they sounded north of us. We ran to the bank, and asked our boatmen, moored below, if they heard them, and if so in what direction. They pointed south!

Schurr, Henry S.; *Nature*, December 7, 1899, pages 127-128

Shortly after my arrival (as District Superintendent of Police in Backergunge) I received a letter . . . asking me to try and elucidate this phenomena of the Barisal Guns.

There are two special occasions to which I would draw attention: The first in February 1891, when from the southernmost outpost, Chaltabuni, I followed the reports for some forty miles out to sea; the second, mentioned in my letter to the Surveyor-General of Bengal, when, in August 1894, for more than six hours, I followed the reports without getting any appreciably nearer, and also never hearing them to the north of me.

(From Report to Geological Surveyor-General Bengal)

These Guns are heard most frequently from February to October, and seldom in November, December or January. One very noticeable feature is their absence during fine weather, and they are only heard just before, during, or immediately after heavy rain.

These Guns are always heard in triplets, i.e., three guns are always heard, one after the other, at regular intervals, and though several guns may be heard the number is always constant, i.e., the interval between the first and the second is the same as the interval between the second and the third, and this interval is usually three seconds, though I have timed it up to ten seconds. The interval, however, between the triplets varies largely, from a few seconds up to hours and days. Sometimes only one series of triplets is heard in a day; at others, the triplets follow with great regularity, and I have counted as many as forty-five of them, one after the other, without pause.

The report is exactly like the firing of big guns heard from a distance with this peculiar difference, the report is always double, i.e., the report has (as it were) an echo . . .

The report varies little in intensity, and I cannot recollect that

there was much difference in the sound, whether heard at Barisal itself or some 70 or 80 miles to the south at the extreme end of the district. The state of the atmosphere may affect it, but to no appreciable extent.

NOTE: The Barisal Guns seem to occur over a large area. It is difficult to know if all the accounts reported were from the same source or whether observations of several phenomena were included as suggested by H.H. Godwin-Austin in his article (*Nature*, January 16, 1896, page 247). Some of the unexplained sounds in the area were mistaken for earthquake noises, suggesting the region had some earthquake history. However, the Guns do not seem directly related to seismic activity.

Coffman, J.L. and Von Hake, C.A.; *United States Earthquakes*, 1972, U.S. Departments of Interior and Commerce

On February 15, 1972, at 1852 (6:52 p.m.) New York; the press reported that telephone calls were received from Golden Bridge, Lake Kitchawan, Truesdale Lake and Waccabuc. Calls also came from Cross River and from an observer near the Connecticut border. At a home in North Salem, an observer thought his furnace had exploded.

NOTE: Whatever was reported was seemingly not picked up on seismic stations nor does this report say what the telephone callers heard or felt. However, a comparison with a boiler explosion suggests a loud noise and some house shaking. These areas have experienced seismic activity.

Coffman, J.L. and Von Hake, C.A.; *United States Earthquakes*, 1973, U.S. Departments of Interior and Commerce

February 3, 1973. Between 1215 and 1300 the press reported that a disturbance, possibly an earthquake, shook houses and rattled windows at Block Island, . . . Bristol, Narragansett Bay, Jamestown, Newport, in Rhode Island; and Cape Cod, Dartmouth, Middleboro, New Bedford, in Massachusetts. A Bristol, R.I. observer said: "The whole house shook and we ran into the street." Noises like an explosion or sonic boom were heard in many areas. The disturbance was not reported at seismograph stations in the area.

NOTE: A MM V intensity was assigned to this event although not a recorded earthquake. Block Island, R.I., was an epicenter for an earthquake in February 1883 and Narragansett Bay in 1965 and 1967.

#### NOISES WHICH OCCUR AT LEAST ONE HOUR PRIOR TO AN EARTHQUAKE

Toksoz, M.N.; "East Anatolian Earthquake of 24 November 1976,"

*Nature*, Vol. 270, 1 December 1977, page 423

There were no foreshocks felt along the fault zone before the main shock on 24 November 1976. In two villages along the western half of the fault trace, where displacements were highest, noises resembling thunder were heard several times during the week preceding the quake.

Bollinger, G.A., and Hopper, M.G.; "Virginia's Two Largest Earthquakes - December 22, 1875 and May 31, 1897," *Bulletin of the Seismological Society of America*, Vol. 61, No. 4, page 1036, August 1971

Earthquake sounds are reported to have begun 4 weeks earlier, on May 3, 1897, when another earthquake, this one of intensity VI, was felt in southwest Virginia, (*Richmond Dispatch*, June 3, 1897). That shock was centered some 30 km to the south of Pearisburg near Pulaski, Virginia, and was generally felt in Giles County, where it "loosened some bricks from old chimneys and was accompanied by considerable noise." Between May 3 and May 31, many similar noises were heard in Giles County, but no other shocks strong enough to attract individual attention were felt. The *Richmond Dispatch* reports that for a week or more before the earthquake of Monday, May 31, "people throughout Giles County were much disturbed by subterranean noises, and all day Monday detonations like the explosion of distant artillery were heard throughout the county." Also, Campbell (1898) states "the noise did not stop with the main shock, but tremors and rumblings or sharp reports" are described as "occurring during the entire night following the shock". . . . Earthquake sounds are commonly reported in connection with Virginia shocks (Bollinger, 1969).

Templeton, E.C.; "Subterranean Sounds Heard in the West Indies," *Bulletin of the Seismological Society of America*, 5:171-173, 1915.

In the *Bulletin Semestrial de L'Observatoire Meteorologique Seminaire-college St. Martial, Port-au-Prince, Haiti*, January-June 1914, are some interesting notes concerning the rumbling sound, popularly known as the "gouffre," which is heard frequently in the West Indies. There appears to be a difference of opinion as to its cause, some claiming that the sound is related to seismic disturbances.

Mr. Maxwell Hall, British government meteorologist at Jamaica, is authority for the following:

At the beginning of January 1907, before the great earthquake of January 14th of that year, similar noises were heard at Mandeville and in other parts of the parish of Manchester, and at certain places in the parish of St. Elizabeth. They were heard several times at the same places, and were mistaken for noises of distant

thundering or of the firing of large caliber cannon.

NOTE: A typical description from the *Bulletin Semestriel* is as follows: "Le gouffre est un phenomene acoustique assez frequent. Les habitants appellent gouffre un bruit sourd, semblable a un coup de canon tire dans le lointain ou a un roulement de tonnarre." (page 130) [. . . a dull noise resembling a cannon-shot fired in the distance or rolling thunder, Au]. In the Templeton article quoted above, a similar description is provided from Mole St. Nicolas, Haiti: "The noise was repeated several times during the night . . . It sounds like the rolling of thunder, with loud detonations repeated two or even three times." Gouffres have also been considered noises without direct association of seismic activity.

Mallet, Robert; *Report of the British Association*, September 1854, Murray, London 1855.

The following are excerpts from Mallet's catalogue of recorded earthquakes from 1600 B.C. to A.D. 1850.

Subterranean noises were heard at 10 PM [(2200) the earthquake occurred on August 28, 1792 at 0100 in East Haddam, Connecticut]. (page 31)

Dull rumblings were observed three or four times during the preceding night [referring to an earthquake at 0520 in La Tour, France, on April 22, 1808]. (page 76) Noises have been constantly heard at the place since the 24th but no shocks, except the two on this morning, [again referring to La Tour and quakes on April 30, 1808 between 0200 and 0300 and at 1145].(page 78)

NOTE: Between May 11 and May 17 La Tour and the area continued to have loud explosions and intermittent earthquakes, (page79-82) but the Vassali-Eaudi's account from which Mallet took the information ceased on May 17, 1808.

Milne, David; *Edinburgh New Philosophical Journal*, Vol. 31, 1841

November 5, 1789, Crieff and Comrie [Scotland] at 6 PM. Violent shock, accompanied by a noise like the discharge of distant artillery . . . for two months previously, a rumbling noise like that of distant thunder, had been heard at Lawers House. (page108)

1795, June 19, Comrie - A rumbling noise in bowels of earth. July 14, Comrie, two or three rumbles in evening. July 25, Comrie. A loud noise and smart shock at 6:30 PM. (Vol. 31, page 111). 1801 September 18. At Comrie a shock this week. Several rumbles during preceding part of week. (Vol. 31, page 114)

Mead, Dale F.; "How the Chinese Predict Earthquakes" - *Science Digest*, March 1976, page 57

The volunteers were alerted to earthquake warning signals that had been vividly described in the chronicles of past generations . . . . Some accounts said that sound like thunder or cannon fire could be heard coming from the ground in the days and hours just before an earthquake . . . . The scientists claimed that the first documented life-saving evacuation, based on cannon-like rumblings, was ordered more than a century ago, in 1855.

McKinley, C.; "The Earthquake, 1886"; *Yearbook 1886 - City of Charleston*, South Carolina, Walker, Evans & Cogswell Co. 1886, page 404

On the morning of Friday, August 27 [1886], he [Capt. Jervey] was descending the stairs of his house between four and five o'clock, when he distinctly felt the shock which was observed by other persons in the city and in Summerville, at that hour. [There were four shocks in Summerville on Friday the 27th at 0440, 1320, 1457 and 1630]. He went out to the Jetties at the entrance to the harbor, where he remained until 2 o'clock P.M. He and others with him heard an "incessant rumbling" all the morning while on the jetty, the sound being mistaken for thunder below the horizon, though the remark was made at the time by Capt. Jervey, that it was "very peculiar thunder." No vibration was perceived in the structure of the jetty. . . .

#### NOISES ACCOMPANYING OR MOMENTARILY PRECEDING AN EARTHQUAKE

Noises preceding an earthquake shock are of particular interest since the sound wave in the atmosphere travels at a much lower velocity than the ground disturbance. Observations of sounds before shocks indicate an atmospheric disturbance (gas escape?) prior to the ground disturbance.

Mallet, Robert; *Report of the British Association*, 1850, page 43

In most earthquakes perhaps, certainly in many, a sound is heard before the great shock . . . the great Lisbon earthquake "began with a noise like the rumbling of carriages, which grew gradually louder until it equaled the loudest artillery and then the great shock occurred." (Phil. Trans. Vol. xlvi. xlix. lvii).

Milne, David; Edinburgh; *New Philosophical Journal*, Vol. 31, 1841, pages 92-122 and Vol. 32, 1842, pages 106-127

A man traveling on foot, in the mountain south of Relujas gave the following account. He was first alarmed by a sudden and tremendous noise as of a rushing wind, which came sweeping up the hills like a roar of water. This was instantly followed by a rumbling sound or rhombo,--and the ground was then sensibly heaved up and down under his feet. (Vol. 31, page 118)

that swish or roar like wind and "hard" sounds like loud rumblings, explosions or cannon fire; swishing may indicate escaping gases.

The shock of the 23rd [Comrie, Scotland, October 23, 1841] at half past 10 PM . . . which was attended with great tremor or heaving of the earth, was accompanied with a noise in nature and intensity indescribably terrific.--that of water, wind, thunder, discharge of cannon, and the blasting of rocks, appeared combined.(Vol. 32, page 122)

Mallet, Robert; *Report of the British Association*, 1850, 1852, 1853, and 1854

A few example excerpts from Mallet's catalogues:

- 1133 August 4; In England; Very Violent; Preceded by a very loud subterranean noise. (1852, page 25)
- 1334 Middle of Autumn; Constantinople, Syria and Egypt; Many and violent shocks; Accompanied in Constantinople by atmospheric commotion. (1852, page 39)
- 1682 May 2 Between 2 and 3 AM; throughout the whole of Savoy,Switzerland, Provence, Alsace, Burgundy and as far north as Paris; Several Shocks. At Remiremont they reoccurred constantly for some weeks; Accompanied by loud subterranean noises and agitation in the air. Flames came forth from the earth in various places, particularly at Remiremont on the Mosells. (1852, page 94)
- 1772 February 18; neighborhood of Kola, Lapland, Russia; An earthquake lasting about a minute; Preceded by noise like that of a carriage upon pavement. (1853, page 172)
- 1804 October 18; In Tuscany; the most severe of all the shocks felt this month; accompanied and followed by rhombi or dull aerial noises. (1854, page 60)
- 1805 February 11; Vitre (Ille de Vilaine); One shock, several however were felt at places near; Preceded by an extraordinary noise lasting five or six seconds, and ending in a loud explosion and the shock. (1854, page 61)

Marvin, C.F.; "Report Upon Earthquake of October 31, 1895," *Monthly Weather Review*, October 1895, page 375

Fred J. Cross reported from Keystone, South Dakota: The "shock was preceded by a rushing or hissing sound for 3 or 4 seconds, like the wind blowing through bush. It is followed by a rumbling sound, similar to a heavy wagon on hard ground; this lasted for 2 or 3 seconds; then came this heavy jarring shock . . ."

McKinley, C.; "The Earthquake, 1886" *Yearbook 1886 - City of*

Charleston, South Carolina, Walker, Evans & Cogswell Co., 1886  
pages 342-441

While engaged in his usual duties, on the second floor of the *News and Courier* . . . the writer's attention was vaguely attracted by a sound which seemed to come from the office below and was supposed for a moment to be caused by the rapid rolling of a heavy body, as an iron safe or a heavily laden truck, over the floor . . . For perhaps two or three seconds the occurrences excited no surprise or comment. Then by swift degrees, or all at once . . . the sound deepened in volume, the tremor became more decided . . . and then all was bewilderment and confusion. (page 349-350)

The sound, when first noticed, resembled a squall at sea, and was thought for a moment to indicate the approach of a tornado. Immediately afterward the tremor of the building began to be felt . . . (page 404)

Dr. Parker says, "I had just reached a point on Tradd Street . . . when I heard a roaring sound apparently in the direction of James Island . . . southwest of where I stood. I made up my mind that a cyclone was coming, and instinctively turned towards the direction indicated, confidently expecting to see the air filled with the flying debris from James Island. Seeing that the sky was perfectly clear, I stood awaiting developments, when I heard another and louder roar coming from the northwest. I then began to feel the vibration of the earth . . ." (page 408)

Bollinger, G.A. and Hopper, M.G.; *The Earthquake History of Virginia 1900-1970*, Virginia Polytechnic Institute, 1972, page 67

Referring to an earthquake on November 19, 1969 of MM IV-V an observer in Chase City, Virginia, wrote: "Sounded as if there had been an explosion then the house seemed to react as if this had taken place in the basement." In Glasgow, Virginia, describing the same earthquake, another observer said: "Very much like the sound of a high speed jet at high altitude or some other booming effect. A long, rolling roar causing the entire house to shake . . ."

Personal Communication from Mahwah Police, Mahwah, New Jersey  
Citizens called the Mahwah police station to report explosions from the base of Mount Ramapo just prior to feeling the earth tremor. *The Bergen Evening Record*, Hackensack, New Jersey, reported one observer as saying, "I heard a rumbling sound that sounded like thunder or a big truck passing my house." (July 2, 1978, B-5)

#### LIGHT PHENOMENA

Lights associated with earthquakes have been the object of intensive



studies particularly in Japan. There have also been numerous descriptions of other types of light phenomena. Included in this Appendix are a few varied examples from historical accounts.

Ganong, W.F.; "The Fact Basis of the Fire (or Phantom) Ship of Bay Chaleur," *Bulletin of the Natural History Society of New Brunswick*, Barnes & Co., New Brunswick, No. XXIV, Vol. V, Part IV, 1906, pages 419-423

Until a short time ago I regarded the fire-ship as a pure fiction, with no basis other than the proneness of humanity to see wonders where they are expected, or where others say they exist. But as a result of two visits to that country, during which I questioned many residents on the subject, I have had to change my opinion; and I now believe there is really some natural phenomenon in that region which manifests itself in such a way as to be imaginable as a vessel on fire . . . .

The information I have myself been able to collect from those who have seen the light is as follows.

Four years ago Captain Turner of Riverside, Albert County, a clear-headed sea captain, told me, in answer to my mention of the fire-ship as a freak of the imagination, that he had himself seen it and hence knew it to exist. Later, on my first visit to Caraquet, I was told by a lady in whose word I have absolute confidence, that her attention was attracted one night by a light off Caraquet, which looked so much like a vessel afire that she supposed it to be one of her husband's schooners, and called him in alarm, only to find that it was the fire-ship. A prominent resident of Miscou, Mr. James Harper, told me he has seen it but once, in the winter on the ice off Clifton. It was seemingly some ten miles away and kept rising and falling, dying down to a very small scarcely visible flame, then rising slowly into a column "looking thirty feet high." It was not in the form of a ship, but a column, but people told him it was the fire ship. He was told it preceded a storm, but he took notice and no storm followed. Mr. Robert Wilson of Miscou, who sails much on Bay Chaleur tells me he has seen the fire-ship, (or as he calls, it the "burning ship") several times. The time he was nearest it was about eleven years ago off Caraquet on a very dark night. The light appeared ahead, and finally he came near and passed within 100 yards to windward of it, so that he saw it with perfect clearness. It was somewhat the shape of a halfmoon resting on the water, flat side down, or like vessel on the water with a bowsprit but no masts etc., and "all glowing like a hot coal. . . ." On other occasions he has seen it, at various distances. . . . Sometimes it looked somewhat like a ship, sometimes not, and sometimes it vanished while he was watching it. Usually it is danc-

ing or vibrating. Again he has seen it as one tall light which would settle down and rise again as three, which would again settle, and so on. . . . Grouping together all the evidence it seems plain--*first*, that a physical light is frequently seen over the waters of Bay Chaleur and vicinity; *second*, that it occurs at all seasons, or at least in winter as well as in summer; *third*, that it usually precedes a storm; *fourth*, that its usual form is roughly hemispherical with the flat side to the water, and that at times it simply glows without much change of form, but that at other times it rises into slender moving columns, giving rise to an appearance capable of interpretation as the flaming rigging of a ship, its vibrating and dancing movements increasing the illusion; *fifth*, its origin is probably electrical, and it is very likely a phase of the phenomenon known to sailors as *St. Elmo's Fire*.

NOTE: Geochemical exploration in the Chaleur Basin has established high methane contents in the bottom sediments.<sup>101</sup> Ignited combustible gas might provide an explanation for the observed lights. Alternatively, the lights might be the Northern Lights though such mis-identification would not be expected from a naturalist of Ganong's experience.

Anonymous; "Phantom Lights at Sea"; *Scientific American*, Vol. 47, 1882, page 56

A Fulton Market fish dealer gives the following explanation of some of the strange lights, phantom vessels, and other mysterious appearances that puzzle seamen:

"Two years ago I went Menhaden fishing, and one day as we were going up the Sound one of the hands said he hoped we were not going off the Point, meaning Montauk. I asked him why. He seemed kind of offish, but at last let out that he had seen ships sailing about in the dead of night in a dead calm. I laughed at him, but two nights later we came to anchor at Gardiner's Bay, and as it was a hot night we stretched out on deck. In the middle of the night I was awakened . . . I looked, and, sure enough, there was a big schooner about an eighth of a mile away, bearing down on us. There wasn't a breath of wind in the bay, but on she came at a ten-knot rate, headed right for us . . . I yelled to the hands and made ready to jump, when, like a flash, she disappeared. . . . We saw the same thing about a week afterward. The light passed around us and went up the bay. . . . I saw an account of something like this in the Portland papers some time after, and they thought it was very remarkable . . ."

Fuller, Curtis; "Lights of Summerville," *Fate*, July 1962, pages 16-17  
Since we have mentioned fireballs, we feel constrained to tell you

about the strange lights that have intrigued the residents of Summerville, S.C., since last December.

The Charlotte, N.C., *News* reported in mid-March that the lights were discovered by young persons on a date on Sheep Island Road . . . . The light changes color and shape as it scoots up and down the road, sometimes high and sometimes low . . . . Another fellow got so excited when he saw the light he jumped into the car and locked all the doors -- leaving his wife outside.

Norcock, C.J.: "An Atmospheric Phenomenon in the North China Sea," *Nature*, 1893, page 76-77

During a recent wintry cruise in *H.M.S. Caroline* in the North China Sea, a curious phenomenon was seen which may be of interest to your readers. The ship was on passage between Shanghai and the western entrance of the famous inland sea of Japan. On 24th February, at 10 p.m. . . . some unusual lights were reported by the officer of the watch between the ship and Mount Auckland, a mountain 6,000 feet high. It was a windy, cold, moonlight night. My first impression was that they were some fires on shore. . . . To the naked eye they appeared sometimes as a mass; at others, spread out in an irregular line, and, being globular in form, they resembled Chinese lanterns festooned between the masts of a lofty vessel . . . .

On the following night, February 25th . . . curious lights were again observed on the same bearing . . . it was a clear, still, moonlight night, and cold . . . . The globes of fire altered in their formation as on the previous night, now in a massed group, with an outlying light away to the right, then the isolated one would disappear, and the others would take the form of a crescent or diamond, or hang festoon-fashion in a curved line. A clear reflection or glare could be seen on the horizon beneath the lights. Through a telescope the globes appeared to be of a reddish colour, and to emit a thin smoke.

I watched them for several hours, and could distinguish no perceptible alteration in their bearing or altitude, the changes occurring only in their relative formation, but each light maintained its oval, globular form.

They remained in sight from 10 p.m. until daylight (about 5.30 a.m.). . . .

On arrival at Kobe I read in a daily paper that the "Unknown light of Japan" had, as was customary at this season of the year when the weather is very cold, stormy, and clear, been observed by fishermen in the Shimbara Gulf and Japanese waters. The article went on to say that these lights were referred to in native school-books, and attributed to electrical phenomena. . . .

Captain Castle, of *H.M.S. Leander*, informed me that not long ago, the officers of his ship saw lights in the same locality which they thought at first were caused by a ship on fire . . . The uniformity of the bearing renders the theory of there being fires on the shore most improbable. I am inclined to the belief that they were something in the nature of *St. Elmo's Fire*.

Gaddis, V.; *Invisible Horizons*, Chilton Co., Pennsylvania, 1965, pages 91-92

The Rev. Samuel T. Livermore . . . in his book *A History of Block Island* quotes a letter writer in 1811 . . . "The light actually is seen, sometimes one half a mile from shore . . . It beams with various magnitudes. Sometimes it is small, resembling the light through a distant window, at other times expanding to the highness of a ship with all her canvas spread . . ." The Reverend Livermore suggested that gas from petroleum deposits beneath the ocean floor was rising to the surface . . . In 1934 Edwin C. Hill . . . made a personal investigation . . . he wrote: "Hundreds have claimed to have seen the apparition and the 'Palatine Light' is a well-known phenomenon along the New England Coast. There is some kind of light--strange, mysterious, inexplicable--which is seen far out at sea at certain times."

Anonymous; *Nature*, August 1, 1872, page 270

A correspondent of the *Madras Mail*, quoted by the *Times of India* says that on the night of June 15 last the plain to the east, north and northeast of Nandidroog was covered with "many thousands" of lights, which has been observed occasionally in former years . . . As many of the lights were from ten to fifteen miles distant from the reporter's point of view, he conjectures that each flame must have been five to six feet in length. An attempt is being made to find out the cause of the curious phenomenon, the most likely hypothesis being that the lights are caused by the ignition of some inflammable gas escaping in jets from the surface of the earth.

Jones, Daniel; "An Account of Weft-River Mountain," *Memoirs of the American Academy of Arts and Science*, Vol. I, pages 312-315, 1784

NOTE: The following account refers to West-River Mountain or Wantastiquet Mountain. Geologists who have worked on this quadrant of New Hampshire agree the mountain is not an active volcano. This Eighteenth Century study was conducted by Jones at the request of Rev. Joseph Willard, President of Cambridge, later Harvard University. Excerpts of the original is presented here as written including the use of the letter "f" for "s."

On the fourth fide of the Mountain, about eighty rods from the fummit, there has been an eruption . . . The peafants, in the

neighborhood of the Mountain, discovered this place and became puffed with the idea of gold . . . .

They have dug down about seventy or eighty feet; and in some places, where the rocks permit, twenty feet wide; but they are now impeded by the rocks . . . . The external parts of the hole is entirely rock, and in many places much burnt and softened. There are small holes in various places of the rock where they dig, like the arch of an oven, and the rock seems to be dissolved by heat; . . . That there have been various explosions in the Mountain, is beyond a doubt, and in various places, which have occasioned great quantities of stone and rock to fall from the Mountain; but I am inclined to think these explosions are not frequent, as formerly, even fifty years ago; for I am told by ancient people of veracity, who formerly dwelt at Fort-Dummer (opposite the Mountain) that there were frequently explosions, and fire and smoke were emitted.

The last explosion that I recollect, happened about five or six years ago, the noise resembling that of an earthquake, and the earth trembled considerably where I was, about four or five miles from the Mountain; my herd of cattle were greatly terrified thereby, and run together through fear.

NOTE: Seismic activity in this area has been noted but it is uncertain whether the above account is directly related to an actual earthquake.

Deer, J.S.; "Earthquake Light," *Earthquake Information Bulletin*, May-June 1977, Vol. 9, No. 3, pages 18-21

In his 1942 textbook, Perry Byerly described reports of earthquake lights at sea . . . . "At the time of the earthquake off the coast in Northern California in January, 1922, one observer reported a glow at sea which he at first took to be a ship on fire. At the time of the earthquake of October, 1926, centering in Monterey Bay, an observer reported a flash at sea which resembled 'a transformer exploding. . . .'" More recently Yasui has commented on observations of lights during October 1, 1969 earthquake at Santa Rosa, California. The lights were seen extensively over the Santa Rosa area and described in terms of lightning, electric sparks, Saint Elmo's Fire, fireballs, or meteors. Some people also heard sounds like explosions.

Fuller, M.L.; *The New Madrid Earthquake*, U.S.G.S., Washington, D.C. Bulletin 494, 1912, page 46

There issued no burning flames, but flashes such as would result from an explosion of gas . . . . At Knoxville, Tennessee, at the end of the first shock "two flashes of light, at intervals of about a minute, very much like distant lightning" were observed. Farther

east in North Carolina there were reported "three extraordinary fires in the air; . . ." At Savannah, Georgia, the first shock is said to have been preceded by a flash of light.

Mallet, Robert; *Report to the British Association - 1854*, J. Murray, London, 1855

NOTE: Following are a few sample excerpts from Mallet's Catalogue describing lights and flames associated with earthquakes but not volcanic eruptions.

- 1802 October 1; Beauvois in France; At the same time [of the shock] a globe of fire was observed, which moved from E. to W., and disappeared with a loud explosion, leaving behind the smell of sulphur, which remained for a long time. (page 49)
- 1804 August 25; Almeria in Granada [Spain] . . . . At Albugnol five very violent shocks. . . . At Albugnol the heavens were obscured by a dark mist, which resolved itself into a cloud, whence in ten minutes, five terrible flashes of fire (lightning?) issued, and after each flash a shock took place. (page 57)
- 1809 February 3; Czakwar, Hungary; Houses situated on a mountain were observed to be lighted up after the shocks; it was supposed by the reflection of subterranean fire and some openings in the earth caused by the earthquake. (page 86)
- 1823 December 13; Belley near Aim, France; rather severe shocks which lasted some seconds; preceded by an explosion like that of large pieces of ordnances. An inhabitant of Biaonies, who was on top of a hill at the time of the shock, reported that the heavens appeared to be on fire an instant after the explosion, although he saw no meteor. (page 154)
- 1834 September 3; Christiania, Norway; . . . several severe shocks . . . . At Snaasen no shock was felt but it was observed that the sky on the western horizon seemed all on fire and constantly lit up by lightning, although the heavens in other directions were clear. (page 248)
- 1838 January 23; Transylvania and parts of Turkey and Russia; . . . At Orsova in Hungary the shocks were violent. . . . At Orsova in Hungary the shocks were accompanied by terrible subterranean billowings and by flames issuing from the earth. (page 274)
- 1841 March 22; Coblentz along the Moselle; A shock of a second's duration; accompanied by very loud noise. The steersman of one of the steamers declared that he saw a blue flame rise from a hill in the distance, which remained suspended in the air for a time, and then sank and disappeared upon the spot it rose from. (page 303)

Anonymous, *Nature*, May 30, 1872, page 89-90

Immediately following the great shock [April 18, 1872 Inyo, California] men whose judgment and veracity are beyond question while sitting on the ground near the Eclipse Mines, saw sheets of flame on the rocky sides of Inyon Mountain, but half a mile distant. These flames, observed in several places waved to and fro, apparently clear of the ground, like vast torches. They continued for only a few minutes.

Terada, Torahiko; "On Luminous Phenomena Accompanying Earthquakes," *Bulletin*, Earthquake Research Institute, Tokyo, Vol. 9, 1931, pages 225-255

NOTE: The following excerpts are of phenomena associated with earthquakes from current and historical studies conducted by Terada and K. Musya.

In the case of the Ansei earthquake of November 1855 different forms of luminous phenomena were reported: [from Musya] "Before the time of the shock a sudden luminosity was seen towards NE, which was so bright that the coloured patterns of their [party of 19 fisherman] clothes could be well discerned. Soon afterwards, a horrible roaring sound was heard from underneath the sea . . . . At the same time a mass of flames went flying through the sky accompanied with sound."

1924 January 15, earthquake in Tanzawa-yama district: A luminosity was seen in Yokosuka at the time of the shocks . . . Mr. K. Hattori . . . was awakened by the first shock and hurried out of door, when he happen to observe a pillar of fire over the roof of the house towards N . . . . Two persons saw the same phenomenon.

Examples from Idu Earthquake of 1930 . . . a number of fisherman who were about to set their boats afloat in the evening previous to the earthquake observed a spherical luminous body to W of Mt. Amagi which moved toward NW with considerable speed. This fire-ball was seen at 4:00 p.m. (1600) of the 25th while the severe shock occurred at 4:30 a.m. (0430) the next morning. Three other examples of unusual light phenomena seen before midnight of the 25th in different places near the epicenter are given in Musya's paper . . . . Several observers compare the phenomena to the beam of a search light. Fire-balls are also repeatedly mentioned. It may be noticed that the fire-balls and also the funnel or trumpet form of luminosity were mostly seen near the epicentral district.

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Corliss, William R.; *Strange Phenomena-A Sourcebook of Unusual Natural Phenomena*, Volumes G-1 and G-2, published by author Glen Arm, Maryland, 1975

Corliss, William R.; *Handbook of Unusual Phenomena*; The Sourcebook Project, Glen Arm, Maryland, 1978

NOTE: The two collections of Corliss generally contain the same references although the *Handbook* has been updated. References for a number of the articles cited in Appendices II and III were initially found in the Corliss collection, although the originals were then examined. These books are the most current collections of reports of unusual noise events.

Everden, Jack F., (project manager); *Abnormal Animal Behavior Prior to Earthquakes* - Proceedings of EHRP Conferences I, Menlo Park, California, October 22-23, 1976 (NTIS #PB-263 485)

NOTE: These proceedings contain 19 articles on varying facets of known and historical animal behavior associated with earthquakes, as well as current research work in the field.

McKinley, Carl; *Yearbook 1886 - City of Charleston*, South Carolina, Walker, Evans and Logswell Co., 1886 page 342-441

NOTE: This account of the Charleston earthquake is one of the most thorough eyewitness reports available in the historical literature, on an earthquake, precursors and aftermath.

Mallet, Robert; *Report of the Twentieth Report of the British Association - 1850*, J. Murray, London, 1851, pages 1-89

NOTE: The first report by Mallet deals with descriptions and effects of earthquakes as of the mid-Nineteenth Century. It is a fascinating piece of journalism and scientific investigation. The following three reports are an extensive catalogue of over 5,000 earthquakes, their effects and precursors.

Mallet, Robert; *Report of the Twenty-second Meeting of the British Association - 1852*, J. Murray, London, 1853, pages 1-176

*Report of the Twenty-third Meeting of the British Association - 1853*, J. Murray, London, 1854, pages 118-212



*Report of the Twenty-fourth Meeting of the British Association - 1854*,  
J. Murray, London 1854, pages 1-326

Milne, David; "Earthquake Shocks Felt in Great Britain", *Edinburgh  
New Philosophical Journal*, Vol. 31, 1841, pages 92-122 and Vol. 32,  
pages 106-127

### APPENDIX III

#### ACCOUNTS OF OTHER EARTHQUAKE PRECURSORS

The venting of smoke, fumes, steam, mud, and sand have occurred during major earthquakes with or without sounds. Uneasy behavior of animals, such as howling dogs and neighing horses, the appearance of deep-water fish on the surface, and floating dead or stunned fish, have been observed before and during earthquakes. Fluctuations in water levels in wells accompanied by differences in smell or taste have been reported before earthquakes.

Following are some examples of historically reported phenomena other than lights or noises.

The following excerpts are from Mallet, 1852, 1853 and 1854.

NOTE: The great Lisbon Earthquake of 1755 November 1. Reports of shocks from Iceland to Morocco and Bohemia to the West Indies.

At Madrid the water in the wells rose several fathoms a little after each shock. (1852, page 164)

Toulouse, Angouleme, Bordeaux . . . . The waters appeared to boil, and change color. (1852, page 165)

British Isles . . . . The waters of a pond near Reading appeared to boil, and were raised over their banks to the extent of 20 inches . . . . At Cranbrock in Kent the water in some fishponds rose upon one bank, then retired, and rose on the opposite bank . . . . The fluctuations lasted about one quarter of an hour and were attended by loud noises, sand also being thrown up in great quantity from the bottom. (1852, page 169)

1782 May 23; near the Lake of Brusjo, in Westnorrland, Sweden, *probably* an earthquake, a loud noise was heard like thunder, and the waters of the lake rose in an extraordinary manner . . . .

1785 October 15; Terni [Italy]. At Pie-di-Lugo several small fumeroles opened from which there came forth smoke and an odour of sulphur. (1854, page 9)

1797 February 20; Cumana (Venezuela?) Half an hour before the violent shocks a smell of sulphur was observed. (1854, page 38)

1825 March 2; Algeries toward the Canary Isles; Some hours before this first shock all the springs and wells dried up.

Fuller, Myron L.; *The New Madrid Earthquake*, Washington, D.C., U.S.G.S. Bulletin 494, page 45

Odors and vapors,--Sulphurous or otherwise obnoxious odors and vapors were an attendant feature of the earthquake at many

points, as stated by nearly every writer . . . Hildreth speaks of the escape of sulphur gas through the cracks tainting the air and impregnating the water for a distance of 150 miles so it was unfit to use. Another observer . . . states that although the air was clear at the time of the shock, within five minutes a vapor with a disagreeable smell and producing a difficulty of breathing impregnated the atmosphere.

McKinley, C.; "The Earthquake of 1886," *Yearbook 1886 - City of Charleston*, South Carolina, Walker, Evans and Cogswell, 1886, pages 342-441

Immediately after the great shock on Tuesday [August 31, 1886] night a strong odor, remarkable for the presence of sulphur gas, permeated the atmosphere, and was perceptible through the night. [Mt. Pleasant] The same odor was detected in Charleston, but was there lost in others of a more offensive character. (page 366)

One of the public wells in the village, about twenty feet in depth, had filled with soft mud that was forced upward with so great an energy as to throw off the covering of the well and overflow the Street . . . A large basin or sink in the village, which was dry on Tuesday, was likewise discovered to be filled with fresh water. (page 365)

Anonymous; "Prediction of the Haicheng Earthquake," EOS, Transactions of the American Geophysical Union, Vol. 58, 1977, pages 236-272

Water wells at the Dingjiagou Production Brigade, located 10 km north of the epicenter were reported to have become artesian on the morning of February 4. The wells are cased to bedrock at about 12 m and the water raised by pumps . . . The water was reported to have turned muddy and oily on February 3, the same day that the first foreshocks were felt. At 0800 on February 4, 1975, the well was flowing freely at the surface and by noon had increased . . . [The 7.3 Richter earthquake occurred at 1936 on February 4] Certainly there was no artesian flow on February after the Haicheng earthquake . . . (page 251)

Liao-ling Province Meteorological Station, "The Extraordinary Phenomena in Weather Observed Before the February 1975 Hai-Cheng Earthquake" - Translated January 4, 1977, from *Acta Geophysica Sinica*, Vol. 20, No. 4, October 1977, page 270-276

During the month before the quake a gas with an extraordinary smell appeared in the areas including Tan-tung and Liao-yang. This was termed "earth gas" by the people in the area . . . A certain commune member in Fung-hsing-hsien in fact saw gas bubbling out of a ditch. According to an incomplete survey, this "earth gas" appeared quite a few times: It was noticed on

December 24, 1974, January 14, 15, 22, 27, 30, February 3, 1975, in many areas.

Many areas were covered with a peculiar fog (termed "earth gas fog" by the people) just prior to the quake. The height of the fog was only 2 to 3 meters. It was very dense, of white and black color, non-uniform, stratified and also had a peculiar smell. It started to appear 1 to 2 hours before the quake and it was so dense that the stars were obscured by it. It dissipated away rapidly after the quake.

The area where this "earth gas fog" appeared was related to the fault . . . lines running in the NWW direction centered at the epicenter . . .

We suspect that fissures may form during these processes and the channels allow the heat and the gas to escape from the deep earth.

Mallet, Robert; *Report of the British Association*, 1854, pages 184-185

1827 November 16; Fe-di-Bogota to Pasto, Colombia; Violent detonations followed the shock, occurring at intervals of thirty seconds with wonderful regularity. From some of the clefts quantities of gas were discharged by which rats and serpents were found to be asphyxiated . . .

Anonymous; "Offshore Burst of Gas Seen as Possible Link to Quake," *Santa Barbara News*, California, August 17, 1978, page A1

Just four days before the earthquake rocked Santa Barbara Sunday, a burst of high pressure gas set off emergency equipment at an exploratory well in the channel . . . The U.S.G.S. Scientists are trying to determine "whether the earthquake could have caused the pressure or whether the pressure could have caused the earthquake . . ." Wayland, who is directing the study, . . . said it's conceivable the increased pressures resulted from changes in the earth as the quake was developing.

#### VENTING SAND, MUD, AND WATER

Mallet, Robert; *Report of the British Association*, 1853, 1854

1757 July 15; 6:15 p.m. (1815); Sully Island and Cornwall [British Isles] . . . On the strand at Penzance unusual marks were observed in the sand at 10 a.m. Where it was generally smooth a space of 100 square yards was covered with little elevations like mole-hills with holes in the top, "as if something had issued thence," and separated by little depressions of equal diameter. From one of these depressions a jet of water of the size of a man's wrist issued a phenomenon never observed before or after. (1853, page 132)

1777 September 30; Macaluba, near Girgenti, Sicily; Attendant on

- an eruption of a mud volcano. Loud noises, like the roaring of the sea, were heard to the distance of three miles (1853, page 188)
- 1809 December 5; Cape Town [South Africa], . . . Muddy water was thrown up to the height of 6 feet from some small holes which opened in the sandy soil (1854, page 86)
- 1835 February 20; Santiago, Chili; Great fissures opened in the earth, from which gases and muddy and salt water were in many places thrown out. (1854, page 252)

Penick, James Jr.; *The New Madrid Earthquakes of 1811-1812*, University of Missouri Press, 1876, page 39

Great amounts of liquid spurted into the air.

"It rushed out in all quarters, bringing with it . . . carbonized wood, reduced mostly into dust which was ejected to the height of from ten to fifteen feet, and fell in a black shower, mixed with the sand which its rapid motion had forced along; at the same time, the roaring and whistling produced by the impetuosity of the air escaping from its confinement, seemed to increase the horrible disorder of the trees which everywhere encountered each other, being blown up, cracking and splitting, and falling by thousands at a time. In the meantime, the surface was sinking, and a black liquid was rising up to the belly of my horse, who stood motionless, struck with terror.

These occurrences occupied nearly two minutes; . . . and the whole surface of the country remained covered with holes, which . . . resembled so many craters of volcanoes, surrounded with a ring of carbonized wood and sand, which rose to the height of about seven feet."

(From the account of Bringier, "Notices of the Geology," pp. 20-21.)

McKinley, C.; "Earthquake of 1886," *Yearbook 1886 - City of Charleston*, South Carolina, Walker, 1886, pages 342-441

[From *Charleston News and Courier*] "The first plain indications of the earthquake beyond the city limits were found at Disher's Farm, about 3 1/2 miles from the Battery. There the appearances were that there had been eruptions all over the farm. The marks of this eruption consisted in extensive cone-shaped mounds of clay and sand, . . . which bore the resemblance of large ant hills, of heights varying from a few inches to several feet." (page 368)

In addition to the fissures and craterlets . . . there was another class of openings . . . commonly called "geysers" . . . water, mud and sand were ejected from them in varying quantities, the sand and mud remaining when the water subsided. (page 369)

[Eyewitness account of J.K. Blackman]

"Upon reaching my garden . . . I was attracted by the sound of rushing water . . . on going to the street I saw one of the old fire-wells . . . spouting up a solid column of water over two feet in diameter, to a height of fully ten feet. [McKinley observes that spouting wells occurred in other parts of Charleston]. When I examined the well the next day, I found it nearly filled with white sand; the pavement for several yards around was torn up, and the sand had been forced up between the bricks." (page 412)

#### WEATHER

"It has certainly been sometimes remarked that great heat has preceded an earthquake, but there have been fully as many examples where very violent earthquakes have occurred at all degrees of atmospheric temperature . . . so that heat preceding an earthquake can by no means be considered as a regularly occurring phenomena." (Von Huff quoted in Mallet, 1850, page 70)

The most convincing example of abnormal temperature variations and earthquakes is found in an account of the Hai-cheng earthquake 1975.

Liao-ling Province Meteorological Station; "The Extraordinary Phenomena in Weather Observed before the February 1975, Hai-cheng Earthquake," translated from *Acta Geophysica Sinica*, Vol. 20, No. 4, October 1977.

January (21st - 31st, approximately) the axis of the "extraordinary area" moved . . . . The temperature showed a marked rise a few days before the quake. The average temperature for January 29 to February 4 was higher than usual by 5° to 6°C. This was especially so on the day of the quake. . . .

This observed temperature increase could be sudden and rapid. On February 3, the day before the quake, the air temperature in the quake area showed a sudden increase and created an area of rapid temperature rise centered at Hai-cheng. Between the hours 8 h to 10 h Hai-cheng showed a temperature increase of 12°C while the distant city of Dairen showed an increase of 2°C. . . . The wind direction generally was in the NE direction, there was no indication of a warming trend. Even if the normal temperature rise after sunrise is taken into account, such a rapid temperature increase is abnormal. The temperature increase usually occurred at night and in the early morning . . . but in the mornings of January 1975 the lowest temperature readings were recorded at irregular hours . . . . Ying-kou-hsien meteorological station observed that the air temperature rose from -22.6°C to -7.6°C, an increase of 15°C, during the hours 23 h, January 5, 1975, to 7 h, January 6. Even if the warm front is taken into account the rise of such magnitude oc-

curring at night is still abnormal. Furthermore, the cities far away from the epicenter . . . did not record such phenomena.

#### EXTREME HEAT NOT VOLCANIC

Both Robert Mallet in *Report of British Association 1854*, page 191 and the *Journal of the Franklin Institute*, Vol. 23, 1837, page 308, recapitulates an unusual experience occurring to the *H.M.S. Volage* (*Volant* in Mallet) anchored at Callao during the Peruvian earthquake, March 30, 1838. The two articles agree in all but the ship's name.

*Journal of the Franklin Institute*, Vol. 23, 1837, page 308

The morning clear and a light breeze from the southward. At 7h.28m. a black thin cloud passed over the ship with very heavy distant thunder. At the same moment we felt the shock of a severe earthquake. I should think it continued seventy or eighty seconds. The ship trembled violently and the only thing I can compare it to is the ship being placed on trucks and driven with rapidity over course paved ground. The ship was moored with two chain cables, and on weighing the anchors a few days after, we found 56 links of the best bower cable much injured, the iron had the appearance of being melted and nearly one-sixth of the link was destroyed . . . The bottom was soft mud, in which the cable was buried. During the earthquake the water alongside was full of little bubbles; the breaking of them sounded like red-hot iron put into water.

NOTE: Mallet's references agree that one of the anchors and part of one chain were damaged in a manner suggesting intense heat. However Mallet adds: "The chain of the second anchor was quite uninjured, as were those of all the other ships in the Bay." Mallet also describes the "bubbles of gas of a sulphurous odor and quantities of dead fish" covering the surface.

This is a curious event. After reading more than 5,000 descriptions of earthquakes, we are struck by the fact that this is the only example of damage, relative to an earthquake, caused by intense heat in so small an area and not obviously connected to volcanic activity.

#### ANIMAL BEHAVIOR

Animal behavior has been considered an indication of earthquakes for centuries. A fascinating distinction of associated causes for different animal reaction was summarized by Robert Mallet in the *Report of the Twentieth Meeting of the British Association in 1850*, page 68: [Sir William] Hamilton says that during shocks, horses and oxen extend their legs widely to avoid being thrown down (an evidence of the velocity of the shock) and that hogs, oxen, horses and

mules, as well as geese, appeared to be painfully aware of the approach of the earthquake of Calabria [1783]; and the neighing of a horse, the braying of an ass or the cackling of a goose . . . drove the people out of their temporary sheds in expectation of a shock.

All birds appear sensible to its approach, but geese, swine and dogs more remarkable than other animals . . . Von Hoff [wrote] "It has been remarked that at such times domestic animals show a decided uneasiness, dogs howled mournfully, horses neighed in an unusual manner and poultry flew restlessly about. These latter phenomena might easily be produced by mephitic vapours, which often ascend to the surface of the earth before the breaking forth of an earthquake. . . ."

The Cirricelli (possibly are Sand-eels) a little deep water fish, . . . which usually lies buried in the sand, Hamilton says "came up to the surface with many others. . . ." This might arise either from actual heat of the sea-bottom and water close to it, or from its being fouled by the commotion or by exhalations into it . . . .

Evernden, J.F. (editor); *Abnormal Animal Behavior Prior to Earthquakes*. Proceedings of EHRP Conference, October 23-24, 1976, U.S. Department of Commerce, Washington, D.C. 1976

A sobering thought that must be kept in mind is the failure of the Chinese to evacuate buildings in either Tangshan or Peking in recent earthquakes . . . . This is important in the present context, as the Chinese have reported many cases of abnormal animal behavior, have asserted the usefulness of such data in predicting times of occurrences, and have said animal behavior was an element in prediction of the Hai-cheng earthquake. Did the Chinese people not report abnormal behavior patterns prior to the Tangshan earthquake, or were their reports ignored because of no "dependable" geophysical signals? (pages 1-2)

There are anecdotal reports by non-scientists from many parts of the world, including such diverse areas as China, Japan, United States, Italy and Guatemala. These reports contain many similarities in the reported behavior of animals before earthquakes, some of these reports having been summarized in the following list, taken from a document distributed to the populace by the Chinese government (PRC):

When cattle, sheep or horses refuse to get into the corral.

When rats run out from their hiding place.

When chickens fly up to the trees and pigs break out from their pens.

When ducks refuse to go to the water and dogs bark for no obvious reason.



When snakes come out from their winter hibernation.  
When pigeons are frightened and will not return to their nests.  
When rabbits with their ears standing jump up or crash into things.  
When fish jump out of the water as if frightened.  
(Logan: page 270)

#### DEAD OR SURFACING FISH

Mallet, Robert; *Report to the British Association* 1853 and 1854

1768 December 29; Bytown in Herefordshire [England]: During this year the sea was turbid off the Shetland Isle and dead fish rose to the surface, phenomena ascribed by v. Hoff to submarine volcanic action. (1853, page 164)

1824 January 30; Manilla, Philippine Isle; Terrible shocks; After the shocks, numbers of dead fish were seen floating on the surface of the river. (1854, page 157)

1841 September 1, Nijne-Tagilsk [Nizhney-Tagil near Perm, U.S.S.R.] A fisherman reported that the fish came up to the surface of the water in a state of great agitation. (1854, page 311)

Coffman, J.L. and von Hake, C.A.; *Earthquake History of the United States*, Department of Commerce, Washington, D.C. 1973

November 18, 1755; Epicenter - East of Cape Ann, Mass. . . . In the Harbors and along the coast, large numbers of fish were killed . . .

Shaw, E.; "Can Animals Anticipate Earthquakes?" *Natural History*, November 1977, page 14-20.

Catfish normally are bottom dwellers, but they have been seen to leap out of the water before earthquakes . . . Working at the Asamushi Marine Biological Station, two researchers discovered a correlation between the response to a mechanical stimulus and the subsequent occurrence of an earthquake . . . The aquariums were installed on wooden tables on which the researchers tapped 3 times a day . . . if the catfish did not react to the tapping, no earthquake tremor would occur, but if they did respond--by jumping--a slight tremor would take place, usually 6 to 8 hours later. . .

Another Japanese scientist . . . examined the relationship between daily fish catch and seismic activity . . . he reported a positive correlation between abundant catches of horse mackerel and seismic activity.

## APPENDIX IV

### CHARLESTON DATA BASE

The Charleston and vicinity events are categorized as occurring during military operations, or not. Events which occurred when military flights were known in Warning Areas W132, 133/34, and W157 have a "Yes" placed under the column "M/O." If no flights were in the Warning Areas, a "No" appears. Events before December 2 or after January 12 have a question mark (?), as flight information is not available. However, if the event occurred before 0700 or after 2000, it is assumed that no military operations were flying. The times supersonic aircraft were in the Areas is given in the column entitled "Military Operation."

The type of event is either observed by citizens, or recorded on the Baptist College seismic network as a vertical displacement. To distinguish the recorded earthquakes during this period, the signals considered not seismic are called acoustic. In many incidents, the event was both observed and recorded. The places given refer to observed events.

The letters after the "Place of Events" are from observer descriptions:

- b = boom, blast, bang
- r = rumble
- cr = connected by rumble (re: 2b cr = 2 booms connected by rumble)
- ln = long
- rw = rattled windows
- rd = rattled doors
- rh = rattled (shook) house
- rf = rattled furniture
- rg = rattled (shook) ground

CHARLESTON EVENTS - DECEMBER-MAY

DATE	CODE M/O	TYPE AND PLACE	TIME EVENT EST	MILITARY OPERATIONS EST
<u>DEC 1</u>	?	Observed, v	1015	
Tue	?	Observed (James Island)	1021	
<u>DEC 2</u>	No	Observed	0830	0925-1030
Wed	Yes	Observed & Acoustic*	0930	
	Yes	Observed	0945	
	No	Observed & Acoustic	1130	
	No	Observed	1600	
<u>DEC 15</u>	-	(Earth tremor-seismic	0215)	
Thu	Yes	Observed & Acoustic	0837	0800-0920
	Yes	Observed & Acoustic	0847	
	Yes	Observed & Acoustic	0958	0930-1110
	Yes	Observed	1013	
	Yes	Observed	1024	
	-	(Earth tremor-seismic	1416)	
<u>DEC 20</u>	No	Observed, v	0856	
Tue	-	(Isle of Palm)		1300-1430
	Yes	Observed, rv	1356	
	-	(Mt Pleasant)		
	-	(Earth tremor-seismic	1841)	
<u>DEC 21</u>	No	Acoustic	0930	
Wed		(not confirmed by Baptist)		
<u>DEC 22</u>	Yes	Observed & Acoustic, v	0848	
Thu	Yes	Observed*, v	0855*	0800-0930
	Yes	Observed, v	0935	
	Yes	Observed*, v	1010*	0925-1045
	Yes	Observed*, v	1015*	
	No	Observed	2130	
	No	Observed	2145	
		*(Mt. Pleasant)		
<u>DEC 25</u>	No	Acoustic	0930	
Sun		(not confirmed by Baptist)		
<u>JAN 3</u>	No	Acoustic	0930	
Tue		(not confirmed by Baptist)		

\*Acoustic is only used to distinguish earth and atmospheric origins. All signals received for Charleston are from the seismic network. Where only vertical recordings on the heliocorder suggest atmospheric disturbance, the events are noted as acoustic.

CHARLESTON EVENTS - DECEMBER-MAY

DATE	CODE M/O	TYPE AND PLACE	TIME EVENT EST	MILITARY OPERATIONS EST
	No	Observed	1100	
	No	Observed, v	1355	
	No	Observed & Acoustic, v (James Island, Mt Pleasant, W. Ashley River)	1453	
<u>JAN 4</u>	Yes	Observed	0900	0800-0915
Wed	Yes	Observed	1047	0910-1100
<u>JAN 5</u>	Yes	Observed	0745	
Thu	Yes	Observed (W. Ashley, Folly Beach, Isle of Palm, Mt. Pleasant)	0810	0730-0830
	Yes	Observed	0830	0730-0851
	Yes	Observed	0937	
		Observed	0942	0800-0950
<u>JAN 6</u>		Observed & Acoustic	0927	
Fri	Yes	Observed	0928	0850-1005
		Observed	0930	
	Yes	Observed	0940	0900-1030
	Yes	Observed (James Island, Folly Beach)	0959	
<u>JAN 9</u>	No	Observed	0800	
Mon	No	Observed (Harleyville)	0930	
<u>JAN 10</u>	No	Observed (Folly Beach)	0145	
<u>JAN 12</u>	No	Observed, rw, rd, rf, b	1125	
Thu	Yes	Observed & Acoustic, rw, rd, b	1410	
	Yes	Observed, rw, rd, b (Charleston, Beaufort, James Island, Isle of Palm, Folly Beach)	1443	
* * * *JANUARY 13 END OF MILITARY OPERATION INFORMATION - EVENTS BEFORE 0700 OR AFTER 2000 ARE ASSUMED NOT CAUSED BY MILITARY OPERATIONS* * * *				
<u>JAN 18</u>		Observed	0726	
Wed	?	Observed (James Island, Mt Pleasant, Summerville)	0727	
	No	Observed (Summerville)	2100	
<u>JAN 25</u>	No	Observed (Columbia)	0500	
Wed				

CHARLESTON EVENTS - DECEMBER-MAY

DATE	CODE M/O	TYPE AND PLACE	TIME EVENT EST	MILITARY OPERATIONS EST
<u>FEB 5</u> Sun	No	Observed (Mt Pleasant)	2400	
<u>FEB 6</u> Mon	?	Observed (Mt Pleasant) (Earth tremor-seismic)	0910 0920	
<u>FEB 7</u> Tue	No	Observed, b (Summerville)	0400	
	?	Observed (Sangaria)	1440	
<u>FEB 8</u> Wed	?	Observed (loud booms - Sullivan Island)	0715 0730	
	?	Observed (vibration only - Ladson)	1215	
<u>FEB 10</u> Fri	?	Observed (James Island)	0710	
<u>FEB 21</u> Tue	?	Observed & Acoustic, b,v	0759	
	?	Observed & Acoustic, b,v	0805	
	?	Observed & Acoustic, b,v	0813	
	?	Observed & Acoustic	0815	
<u>APR 23</u> Sun	?	Observed (Edisto Island, Folly Beach, Mt Pleasant)	1120	
<u>MAY 3</u> Wed		Observed	<u>EDT</u> 0705	
		Observed	0706	
		Observed (Yonges Island)	0720	

DON MORGAN'S REPORTED TIMES & LOCATION

February 21

Sullivan Island	0758
N. Charleston	0802
W. Ashley	0806
Charleston (d'town)	0812
W. Ashley	0813
Hanshan	0815
Summerville	0816
Nortwood Estates	0817

## APPENDIX V

### NEW JERSEY DATA BASE

The New Jersey events are categorized as occurring during military operations, or not. Events which occurred when military flights were known in Warning Areas W107 and W108 have a "Yes" placed under the column "M/O". If no flights were in the Warning Areas, a "No" appears. Events before December 2 or after January 12 have a question mark (?), as flight information is not available. However, if the event occurred before 0700 or after 2000, it is assumed that no military operations were flying. The times that supersonic aircraft were in the Warning Areas are given in the column entitled "Military Operations".

The type of event is either observed by citizens or recorded on the Western Observatory (W), Lamont-Doherty Laboratory (D), or Consolidated Edison (Con E) seismic network as a vertical displacement. In many incidents, the event was both observed and recorded. The places given refer to observed events.

Events observed as lights only have superscript 1 next to the time. If the event was described as both a boom and light, a superscript 2 is next to the observed time. Those events observed as only vibrations have a superscript 3.

NEW JERSEY EVENTS - DECEMBER-FEBRUARY

DATE	CODE M/O	PLACE	EVENT TIME EST	MILITARY OPERATIONS W107 & W108
<u>Dec 2</u>	No	Brigantine	0915	
<u>Fri</u>	Yes	Brigantine	0935	0930-1200
	Yes	Spring Lake	1000	0945-1015
		North Beach	1000	
		<u>ACOUSTIC</u> (3),W,Con E,LD	1004-1007	
		Haledon	1010	1004-1200
	Yes	<u>ACOUSTIC</u> , W	1031	
	Yes	Point Pleasant	1100	
		Farmingdale	1100	
	No	Wall Tnsp	1400	
		Tuckerton	1400	
		Jackson	1500	
	Yes	Bricktown	1500	1427-1634
		Belmar	1500	
		Bricktown	1530	
		Hamonton	1530-1600	
	Yes	Long Branch	1530-1600	
		Aberdeen	1530-1545	
		Spring Lake	1530-1545	
	Yes	Toms River	1540	
		Egg Harbour City	1540	
		Howell Tnsp	1541	
		Red Bank	1545	
		<u>ACOUSTIC</u> (3),LD,W, Con E	1545-1548	
		<u>ACOUSTIC</u> (2)W	1550-1555	
	Yes	Hazlet	1600	
		Monroe Tnsp	1600	
		Freehold	1600	
		Old Bridge	1600	
<u>Dec 3</u>	No	Elizabeth	0100	
<u>Sat</u>	No	Tuckerton	0200-0300	
<u>Dec 7</u>				1434-1628
<u>Wed</u>	Yes	South Amboy	1530	
	Yes	South Amboy	1600	
	No	Randolph	1900	
		Tuckerton	1900	
	No	Tuckerton	1900 <sup>1</sup>	2013-2402
<u>Dec 15</u>	No	<u>ACOUSTIC</u> , W	0847	
<u>Thu</u>		<u>ACOUSTIC</u> , W	0850	
	No	<u>ACOUSTIC</u> , W	1001	
	Yes	<u>ACOUSTIC</u> , W	1007	
<u>Dec 17</u>	No	Panama, N.Y. (3 booms	1430-1530	
<u>Sat</u>		20 mins. apart)		

NEW JERSEY EVENTS - DECEMBER-FEBRUARY

<u>DATE</u>	<u>CODE M/O</u>	<u>PLACE</u>	<u>EVENT TIME EST</u>	<u>MILITARY OPERATIONS W107 &amp; W108</u>
<u>Dec 18</u>	No	Bridgewater	0030-0130 <sup>1</sup>	
Sun	No	New Providence	1800-1830 <sup>1</sup>	
<u>Dec 20</u>	No	<u>ACOUSTIC</u> , Con E	0838	
Tue	No	<u>ACOUSTIC</u> , LD	0852	
	Yes	<u>ACOUSTIC</u> , Con E	1027	1003-1207
	Yes	Farmingdale	1100	
	No	Farmingdale	1845 <sup>1</sup>	
	No	Highland	2100-2200 <sup>2</sup>	
<u>Dec 21</u>	No	Villas	0100-0130 <sup>2</sup>	
Wed	No	Hillsdale	0900-1000	
	Yes	Tuckerton to Long Island	1830-1900	1300-1330, 1345-1415 1428-1632 1845-2017
	Yes	Elizabeth (9 booms in 20 mins) <u>ACOUSTIC</u> , LD	1900 1904	
<u>Dec 22</u>	No	Jackson	0730 <sup>1</sup>	
Thu	No	So. Asbury Park	0830 <sup>3</sup>	
	No	<u>ACOUSTIC</u> (2), W	0924-0925	0955-1200
	Yes	<u>ACOUSTIC</u> (9), W, Con E	1000-1034	
	Yes	<u>ACOUSTIC</u> (2), W	1159-1201	
	No	<u>ACOUSTIC</u> (2), W	1418-1428	
				1438-1644
	Yes	<u>ACOUSTIC</u> (4), W Asbury Park	1545-1600 1600 <sup>3</sup>	
	Yes	Elizabeth	1900	1845-2047
<u>Dec 23</u>				1431-1607
Fri	No	Newark	1900 <sup>1</sup>	
<u>Dec 24</u>	No	Citizen report	0237	
Sat	No	Sloatesburg	0345	
<u>Dec 26</u>	No	Citizen report	0340	
Mon	No	<u>ACOUSTIC</u> , W	1141	
	Yes	<u>ACOUSTIC</u> , W	2020	1945-2045
<u>Dec 27</u>	No	Patterson	0915	
Tue				1306-1523



NEW JERSEY EVENTS - DECEMBER-FEBRUARY

DATE	CODE M/O	PLACE	EVENT TIME EST	MILITARY OPERATIONS W107 & W108
	No	<u>ACOUSTIC</u> , W	1903	
<u>Dec 28</u>	No	<u>ACOUSTIC</u> , W	0854	
<u>Wed</u>	No	<u>ACOUSTIC</u> , W	0956	
	No	<u>ACOUSTIC</u> , W	1128	1306-1523
	Yes	<u>ACOUSTIC</u> , W	1512	1715-1745
				1815-1845
	No	<u>ACOUSTIC</u> , W	1959	
	No	Jersey City	2000-2100 <sup>1</sup>	
<u>Dec 29</u>	No	<u>ACOUSTIC</u> (2), W	1546-1548	
<u>Thu</u>				
<u>Dec 30</u>	No	Stone Harbour	0530	
<u>Fri</u>				1018-1221
<u>Jan 2</u>	No	Livingston	1030-1130	
<u>Mon</u>		<u>ACOUSTIC</u> , W	1132	
<u>Jan 3</u>	No	Villas	1215	
<u>Tue</u>	No	Neptune	2225 <sup>2</sup>	
<u>Jan 4</u>	No	Longport	0200 <sup>1</sup>	
<u>Wed</u>	No	<u>ACOUSTIC</u> (2), W	0804-0812	
	No	<u>ACOUSTIC</u> (2), W	0906-0912	
	No	<u>ACOUSTIC</u> , W	0936	
	No	<u>ACOUSTIC</u> , W	1018	
	No	Villas	1245	1030-1238
		<u>ACOUSTIC</u> , W	1300	1300-1330
				1400-1430
	Yes	<u>ACOUSTIC</u> , W	1518	1427-1623
	No	<u>ACOUSTIC</u> , W	1710	1427-1623
<u>Jan 5</u>	No	Toms River	0152	
<u>Thu</u>	No	<u>ACOUSTIC</u> (3), W	0752-0809	
	Yes	<u>ACOUSTIC</u> (6), W	1039-1100	1000-1030
	Yes	<u>ACOUSTIC</u>	1146	1003-1206
	No	<u>ACOUSTIC</u> (5), W	1330-1355	
	Yes	<u>ACOUSTIC</u> (3), W	1515-1548	1444-1638
		S. Asbury Park	1600	
	Yes	<u>ACOUSTIC</u> (2), W	1622-1631	
	No	<u>ACOUSTIC</u> , W	1725	
	No	<u>ACOUSTIC</u> , W	1800	
	Yes	<u>ACOUSTIC</u> , W	2018	1833-2056

NEW JERSEY EVENTS - DECEMBER-FEBRUARY

DATE	CODE M/O	PLACE	EVENT TIME EST	MILITARY OPERATIONS W107 & W108
<u>Jan 6</u>	No	Wykoff	0900	
<u>Fri</u>	No	Wykoff	0920	0958-1200
	Yes	ACOUSTIC, W	1110	
	No	ACOUSTIC, W	1209	
	No	Wayne	1330	
	No	Pompton Plains	1330	
	No	Wayne	1400	1428-1625
	Yes	Pompton Plains	1600	
<u>Jan 8</u>	No	Patterson	0-0100 <sup>1</sup>	
<u>Sun</u>				
<u>Jan 9</u>	No	Holmdel	0200 <sup>1</sup>	
<u>Mon</u>				
<u>Jan 10</u>	No	ACOUSTIC, W	1137	1045-1115
<u>Tue</u>	No	Keyport	2100-2200 <sup>1</sup>	
<u>Jan 11</u>	Yes	ACOUSTIC, LD	1146	1010-1214
<u>Wed</u>	No	Livingston	2300 <sup>1</sup>	
<u>Jan 12</u>	No	Mountain Lakes	0700 <sup>1</sup>	
<u>Thu</u>	No	ACOUSTIC, LD	0900	
	Yes	Livingston	1030-1130	1000-1030
		ACOUSTIC	1153	1045-1115
	No	Rockaway		
		ACOUSTIC	1457	
<u>Jan 16</u>		39 Acoustic Events	1214-1730	JAN 14 LAST
<u>Mon</u>		38 Times Unknown recorded at Weston		DATA ON MILITARY OPERATIONS
		Largest at Weston	1548	
		Major acoustic signals recorded at Lamont- Doherty	1114 1140 1205 1211 1221 1317 1322 1346 1523 1526 1559	
<u>Jan 18</u>	?	Toms River	1120	
<u>Wed</u>				
<u>Jan 19</u>	No	Long Branch	2200-2400 <sup>2</sup>	
<u>Thu</u>				
<u>Jan 26</u>	No	Toms River/Asbury Park	0600 <sup>2</sup>	
<u>Thu</u>				

## APPENDIX VI

### NOVA SCOTIA DATA BASE

The Nova Scotia events are categorized as either Concorde (C), Associated (A), or Non-associated (N).

Times of events within 15 minutes (before or after) of the calculated Concorde flight time are considered generated by the supersonic aircraft and have the letter "C" under "Code".

Events which are within 30 minutes before or after a calculated Concorde time or which have a description including "double boom" are categorized as Associated, and have the letter "A" under "Code". These events are assumed caused by supersonic aircraft, but not the Concorde. Reports by pilots suggest military operations have been conducted near the Concorde flight path, particularly in January and February. It should be pointed out that these events are not really explained, as records from Canadian military are not available, and the military has not confirmed the pilot observations. Similarly, there is no basis to suggest that Concorde generated these additional booms as, in most cases, the carpet booms have been identified.

The final category of events is Non-associated, designated by the letter "N" under "Code". These are events which occur over 30 minutes before or after Concorde and which do not include a double boom as part of the description. Their source is unidentified.

The letters after the "Place of Events" are from observer descriptions:

b = boom, blast, bang  
r = rumble  
cr = connected by rumble (re: 2b cr = 2 booms connected by rumble)  
ln = long  
rw = rattled windows  
rd = rattled doors  
rh = rattled (shook) house  
rf = rattled furniture  
rg = rattled (shook) ground

The times of the actual events are in Atlantic Standard Time as is the calculated time of event. The actual flight arrival/departure times are Eastern Standard Time.

The actual arrival/departure times for John F. Kennedy Airport are from the FAA Concorde Monitoring Records for the included months. The Dulles Airport times are based on scheduled departures and arrivals unless noted from periodic monitoring by the FAA.

JFK flights are written as aAF0000, aBA0000, dAF0000, and dBA0000. The small a is for arrivals, the small d is for departures. AF denotes Air France, BA denotes British Airways.

Dulles flights are bracketed (aAF0000), (dAF0000), etc; when an asterisk (\*) is placed by the brackets, it signifies a scheduled, not a monitored flight time: (aBA0000)\* is a scheduled British Airways arrival, (aBA0000) is a monitored British Airways arrival.

METHOD OF CALCULATING THE TIME OF ARRIVALS  
IS BASED ON INFORMATION FROM THE AIRLINES

JFK

arrivals:  $T_c = T_a - T^f + Y$

departures:  $T_c = T_d + T^t + Z$

$T_c$  = Time calculated for event at Cape Sable Light

$T_a$  = Time of actual arrival

$T_d$  = Time of actual departure

$T^f$  = Flight time from Cape Sable Light to New York = 52 minutes

$T^t$  = Flight time from New York to Cape Sable Light = 38 minutes

$Y$  = Time a sonic carpet boom would reach Cape Sable Light from the arrival path 48 miles offshore at speed of sound = 4 minutes

$Z$  = Time a sonic carpet boom would reach Cape Sable Light from the departure path 108 miles offshore at speed of sound = 9 minutes

DULLES

arrivals:  $T_c = T_a - T_{fd} + Y$

departures:  $T_c = T_d + T_{td} + Z$

as above except

$T_{fd}$  = Flight time from Cape Sable to Dulles — 66 minutes

$T_{td}$  = Flight time to Cape Sable from Dulles — 47 minutes

## NOVA SCOTIA - JANUARY

DATE 1978	C,A,N CODE	PLACE OF EVENT	ACTUAL TIME	FLIGHT ARR	ACTUAL
			OF EVENT	CALCULATED	ARR/DEP
			AST	TIME	TIME
				AST	EST
<u>1</u>		NO EVENT		0849	aAF0837
Sun	A	Cape Sable Light	0910		
		NO EVENT		1024	aBA1012
	C	Cape Sable Light	1220	1227	dAF1040
	C	Ingomar, rh	1430	(1441)*	(dBA1245)*
		NO EVENT		(1753)*	(aAF1755)*
<u>2</u>		Cape Sable Light	0915	0904	aAF0853
Mon	C	NO EVENT		(1207)	(aBA1209)
	C	Cape Sable Light	1220	1228	dAF1041
		NO EVENT		1418	dBA1231
		NO EVENT		(1509)	(dAF1313)
<u>3</u>		Cape Sable Light	0910	0913	aAF0901
Tue	C	Cape Sable Light	1040	1043	aBA1031
	C	Cape Sable Light	1220	1224	dAF1037
		NO EVENT		(1441)	(dBA1245)
<u>4</u>		NO EVENT		0900	aAF0848
Wed		NO EVENT		1044	aBA1032
	C	Cape Sable Light	1230	1231	dAF1044
		NO EVENT		1430	dBA1243
		NO EVENT		(1753)	(aAF1755)
<u>5</u>		NO EVENT		0904	aAF0849
Thu		NO EVENT		(1208)*	(aBA1210)*
		NO EVENT		1226	dAF1039
		NO EVENT		1430	dBA1243
	A	Cape Sable Light	1605	(1546)	(dAF1350)
<u>6</u>		NO EVENT		0900	aAF0848
Fri		NO EVENT		1115	aBA1103
	C	Cape Sable Light	1235	1231	dAF1044
		NO EVENT		(1441)*	(dBA1245)*
		NO EVENT		(1753)*	(aAF1755)*
<u>7</u>		Ingomar	0845		
Sat	C	Cape Sable Light	0915	0923	aAF0911
		NO EVENT		(1208)*	(aBA1210)*
		NO EVENT		1256	dAF1109
	N	Clarks Harbour	1330		
		NO EVENT		1420	dBA1233
		NO EVENT		(1511)*	(dAF1315)*
	N	Cape Sable Light	1610		
<u>8</u>		Cape Sable Light	0905	0902	aAF0850
Sun	C	Cape Sable Light	1050	1053	aBA1041
		NO EVENT		1245	dAF1058
		NO EVENT		(1441)*	(dBA1245)*
		NO EVENT		(1753)*	(aAF1755)*

DATE 1978	C.A.N CODE	PLACE OF EVENT	ACTUAL TIME OF EVENT AST	FLIGHT ARR CALCULATED TIME AST	ACTUAL ARR/DEP TIME EST
<u>9</u> Mon		NO EVENT NO EVENT NO EVENT NO EVENT		0907 (1215) 1225 1424 (1511)	aAF0855 (aBA1217) dAF1038 dBA1237 (dBA1315)*
<u>10</u> Tue	N C	Cape Sable Light NO EVENT Cape Sable Light NO EVENT NO EVENT	0900 1025	0932 1025 1232 (1441)*	aAF0920 aBA1013 dAF1045 (dBA1245)*
<u>11</u> Wed	C	NO EVENT Cape Sable Light NO EVENT NO EVENT NO EVENT	1050	0907 1048 1230 1425 (1803)	aAF0855 aBA1036 dAF1043 dBA1238 (aAF1803)
<u>12</u> Thu		NO EVENT NO EVENT NO EVENT NO EVENT NO EVENT		0854 (1208)* 1223 1425 (1518)	aAF0842 (aBA1210)* dAF1036 dBA1238 (dAF1322)
<u>13</u> Fri	C C	Northeast Harbour, rh Ingomar Barrington, rf Cape Sable Light	0900 0900 0905 1020	0854 1030	aAF0842 aBA1018
		NO EVENT NO EVENT		(1441)* (1753)*	(dBA1245)* (aAF1755)*
<u>14</u> Sat	C	Stoney Island, rh NO EVENT NO EVENT NO EVENT NO EVENT NO EVENT	0903	0901 (1208)* 1311 1333 (1511)* 1558	aAF0849 (aBA1210)* dAF1124 dAF1146 (dAF1315)* dBA1411
<u>15</u> Sun	C C	Cape Sable Light Barrington, rw, rd Barrington Head, rh, rf Ingomar Northeast Harbour Cape Sable Light Barrington, rw Barrington Northeast Harbour Ingomar	0855 0855 0900 0900 0900 1028 1028 1030 1030 1030	0857 1025	aAF0845 aBA1013
		NO EVENT NO EVENT NO EVENT NO EVENT		1228 1419 (1441)* (1753)*	dAF1041 dBA1232 (dBA1245)* (aAF1755)*

## NOVA SCOTIA - JANUARY

DATE 1978	C,A,N CODE	PLACE OF EVENT	ACTUAL TIME OF EVENT AST	FLIGHT ARR CALCULATED TIME AST	ACTUAL ARR/DEP TIME EST
<u>16</u> Mon	C	Cape Sable Light	0905	0859	aAF0847
		NO EVENT		1032	aBA1020
		NO EVENT		(1204)	(aBA1204)
		NO EVENT		1224	dAF1037
		NO EVENT		1424	dBA1237
		NO EVENT		(1514)	(dAF1318)
<u>17</u> Tue		NO EVENT		0904	aAF0852
		NO EVENT		1032	aBA1020
	A	Cape Sable Light	1230		
		NO EVENT		1246	dAF1059
		NO EVENT		(1441)*	(dBA1245)*
		NO EVENT		1501	aBA1449
		NO EVENT		1522	dBA1335
<u>18</u> Wed		NO EVENT		0856	aAF0844
	N	Lower Woods Harbour, r	1145		
		NO EVENT		1229	dAF1042
		NO EVENT		1423	dBA1236
		NO EVENT		(1810)	(aAF1812)
<u>19</u> Thu		Cape Sable Light	0930		
		NO EVENT			
	A	Northeast Harbour	0945		
		Ingomar	0945		
		NO EVENT		1003	aAF0951
	C	Cape Sable Light	1035		
		NO EVENT		1047	aBA1035
		NO EVENT		(1208)*	(aBA1210)*
		NO EVENT		1323	dAF1136
		NO EVENT		1427	dBA1240
		NO EVENT		(1512)	(dAF1316)
<u>20</u> Fri		NO EVENT		(1441)*	JFK CLOSED
		NO EVENT			(dBA1245)*
	N	Port Saxon, rd	1636		
		NO EVENT		(1753)*	(aAF1755)*
<u>21</u> Sat		NO EVENT		(1208)*	(aBA1210)*
	C	Cape Sable Light	1400		
		NO EVENT		1413	aBA1401
	C	Cape Sable Light	1430		
		NO EVENT		1442	aAF1430
		NO EVENT		(1511)*	(dAF1315)*
		NO EVENT		1848	dBA1701
<u>22</u>		NO EVENT			
	N	Clarke Harbour	0825		
		NO EVENT		0901	aAF0849
	C	Cape Sable Light	1020		
		NO EVENT		1017	aBA1005
		NO EVENT			
	C	Port Saxon	1250		
		Port Saxon	1251		
		NO EVENT		1249	dAF1102
	N	Port La Tour, r, rw	1400		

## NOVA SCOTIA - JANUARY

DATE 1978	C,A,N CODE	PLACE OF EVENT	ACTUAL TIME	FLIGHT ARR	ACTUAL
			OF EVENT	CALCULATED	ARR/DEP
			AST	TIME	TIME
				AST	EST
	A	Clarks Harbour, r Barrington, rw Port Saxon	1430 1430 1432		
	C	Clarks Harbour Cape Sable Light	1433 1433	1433	dBAl248
		NO EVENT		(1441)*	(dBAl245)*
	A	Clarks Harbour, r	1730		
		NO EVENT		(1753)*	(aAF1755)*
		NO EVENT		1755	aAF1608
23 Mon	N	Browns Bank	0550		
		NO EVENT		0901	aAF0849
	C	Browns Bank, 2b	1050	1108	aBA1056
		Barrington, r	1230		
		Ingomar	1235		
	C	Port Saxon	1236	1234	dAF1047
		Port La Tour, r	1237		
		Villagedale, r	1240		
	N	35 mi. S. of Cape Negro Island, rb	1430		
		40 mi. S. of Cape	1430		
		NO EVENT		(1521)	(dAF1324)
	C	Port Saxon	1620	1622	dBAl435
		Ingomar	1622		
		NO EVENT		(1806)	(aBA1808)
		NO EVENT		1913	dBAl726
24 Tue	C	Cape Sable Light	0906	0910	aAF0858
	C	Cape Sable Light	1030	1029	aBA1017
	A	Browns Bank, 2b	1050		
		Villagedale	1230		
	C	Northeast Point	1235	1233	dAF1046
		Port La Tour	1237		
		NO EVENT		1435	dBAl248
		NO EVENT		(1441)*	(dBAl245)*
25 Wed	N	Ingomar	0813		
	C	Cape Sable Light	0905	0912	aAF0900
	C	Cape Sable Light	1025	1040	aBA1028
		Cape Sable Light	1225		
	C	Prospect Point	1235	1235	dAF1048
		Villagedale	1235		



## NOVA SCOTIA - JANUARY

DATE 1978	C,A,N CODE	PLACE OF EVENT	ACTUAL TIME	FLIGHT ARR	ACTUAL
			OF EVENT	CALCULATED	ARR/DEP
			AST	TIME	TIME
				AST	EST
	C	Ingomar, 2b	1433	1431	dBA1244
	A	Baccaro, r, rh	=1500		
	N	Villagedale	=1600		
		NO EVENT		(1753)*	(aAF1755)*
<u>26</u>		NO EVENT		1119	aBA1107
Thu		NO EVENT		(1208)*	(aBA1210)*
		NO EVENT		1223	aAF1211
		NO EVENT		(1511)*	(dAF1315)*
		NO EVENT		1514	dBA1327
	C	Ingomar	1545	1547	dAF1400
<u>27</u>		Clarks Harbour, rh	0900		
Fri		Barrington, rw	0900		
		Northeast Harbour	0900		
		Shag Harbour, rh	0902		
	C	Near Clarks Harbour	0902	0858	aAF0846
		Stoney Island, rh	0903		
		Ingomar, rh	0903		
		Upper Shag Harbour	0904		
		Shag Harbour	0904		
		Doctor's Cove, r	0904		
		Shag Harbour, r	0905		
		Stoney Island, r	0905		
		Clarks Harbour, r	0905		
		Centreville	0905		
		West Head, rd	0905		
		Clam Point	0905		
	A	Barrington	0905		
		Barrington Passage	0905		
		Seal Island	0905		
		Bear Point, rh	0907		
		Villagedale	0908		
		Barrington West, rh	0910		
		Newellton, rh	0910		
		Southside	0910		
		Baccaro, rh	0915		
	A	Shag Harbour, rf	0920		
		Barrington, r	0921		
	A	Cape Sable Light	1022		
		Baccaro	1035		
		Southside, rh	1040		
	C	Stoney Island	1040	1035	aBA1023
		Ingomar, rh	1040		
		Northeast Harbour, rd	1043		
		Clam Point			
	N	Stoney Island	1115		
	N	Near Clarks Harbour	1125		
	C	Barrington	1415	1422	dBA1235

## NOVA SCOTIA - JANUARY

<u>DATE</u> <u>1978</u>	<u>C,A,N</u> <u>CODE</u>	<u>PLACE OF EVENT</u>	<u>ACTUAL TIME</u> <u>OF EVENT</u> <u>AST</u>	<u>FLIGHT ARR</u> <u>CALCULATED</u> <u>TIME</u> <u>AST</u>	<u>ACTUAL</u> <u>ARR/DEP</u> <u>TIME</u> <u>EST</u>
	A	Charlesville	1430		
		NO EVENT		(1441)*	(dBA1245)*
		NO EVENT		(1808)	(aAF1810)
	C	Barrington, rh	1815	1817	dAF1630
	N	Upper Shag Harbour	2200		
<u>28</u> <u>Sat</u>	C	Cape Sable Light	0900	0858	aAF0846
		Stoney Island	0909		
	A	Barrington, 2b	1000		
	N	Bear Point	1045		
		NO EVENT		(1153)	(aBA1155)
		NO EVENT		1228	dAF1041
	N	Barrington, rw, rh	1430		
		NO EVENT		(1513)	(dAF1317)
<u>29</u> <u>Sun</u>		Baccaro	0900		
		Stoney Island	0903		
	C	Barrington, rh	0905	0902	aAF0850
		Near Clarks Harbour	0905		
		Cape Sable Light	0905		
	C	Cape Sable Light, rf	1040		
		Stoney Island	1045	1043	aBA1031
		Doctor's Cove	1045		
	C	Stoney Island	1240		
		Barrington, rh	1240	1238	dAF1051
		Baccaro, 2b	1240		
	C	Northeast Harbour	1430		
		Doctor's Cove	1430	1431	dBA1244
		NO EVENT		(1441)*	(dBA1245)*
		NO EVENT		(1802)	(aAF1804)
<u>30</u> <u>Mon</u>	A	Baccaro	0900		
		Centreville, rw	0900		
		Baccaro, rw	0905		
		Clarks Harbour	0905		
	C	Ingomar	0905		
		Cape Sable Light	0905	0916	aAF0904
		Near Clarks Harbour	0907		
		Stoney Island	0910		
		Baccaro	1115		
		Cape Sable Light	1115		
	A	Ingomar, rh	1118		
		Near Clarks Harbor, r, no b	1118		
		Shag Harbour	1118		

## NOVA SCOTIA - JANUARY

<u>DATE</u> <u>1978</u>	<u>C,A,N</u> <u>CODE</u>	<u>PLACE OF EVENT</u>	<u>ACTUAL TIME</u> <u>OF EVENT</u> <u>AST</u>	<u>FLIGHT ARR</u> <u>CALCULATED</u> <u>TIME</u> <u>AST</u>	<u>ACTUAL</u> <u>ARR/DEP</u> <u>TIME</u> <u>EST</u>
	C	E. Baccaro, rd Centreville, rw	1125 1130	1127	dAF1115
		NO EVENT		(1153)	(dBA1155)
	C	Cape Sable Light Baccaro, rh	1243 1245	1247	dAF1100
		NO EVENT		1451	dBA1304
		NO EVENT		(1518)	(dAF1322)
<u>31</u> <u>Tue</u>	N	Port Saxon, r Newellton	0900 0906		
	A	Browns Bank, 2b	= 0900		
		Newellton	1005		
		Clarks Harbour	1005		
		Baccaro	1008		
		Lower Clarks Harbour	1009		
	C	The Hawk, r	1010	1008	dAF0956
		Barrington, rw	1012		
		E. Baccaro, rd	1012		
		Ingomar, rh	1012		
		Cape Sable Light, r	1013		
		Stoney Island, rh,rw	1015		
		The Hawk, r	1025		
		Cape Sable Light	1025		
		Lower Clarks Harbour	1026		
	C	Barrington, rw, rf	1026	1028	dBA1016
		E. Baccaro	1028		
		Clarks Harbour	1030		
		Stoney Island	1030		
		NO EVENT		1327	dAF1140
	A	Shelburne, 2b	1437		
	C	Shelburne, 2b, rg	1459		
		Stoney Island, rh	1500	(1441)*	(dBA1245)*
	N	Stoney Island	1730		

## NOVA SCOTIA - FEBRUARY

DATE 1978	C,A,N CODE		ACTUAL TIME	FLIGHT ARR	ACTUAL
			OF EVENT	CALCULATED	ARR/DEP
			AST	TIME	TIME
				AST	EST
<u>1</u>	N	Barrington	0910		
Wed	A	Barrington	1009		
		Cape Sable Light, 2r	1012		
		Northeast Harbour	1015		
	C	Clyde River, rh	1015	1011	dBA0824
		Barrington	1015		
		Ingomar, rw	1015		
		Shelburne	1016		
	A	Clyde River	1030		
	A	Cape Sable Light	1040		
	C	Brass Hill, rh	1050	1041	aBA1029
		Cape Sable Light, rh	1052		
	C	Ingomar	1152	1156	aAF1144
		Stoney Island	1153		
	C	Port Saxon to Ingomar	1517	1518	dBA1331
		3b, rw	1520		
		Northeast Harbour	1520		
	C	Villagedale	1530	1530	dAF1343
		Port Joli, rw, r	1530		
		NO EVENT		(1753)*	(aAF1755)*
<u>2</u>	C	Cape Sable Light	0855	0858	aAF0846
Thu		The Hawk	0900		
	A	The Hawk	1015		
	C	Cape Sable Light	1025	1031	aBA1019
	A	Cape Sable Light	1045		
	C	Clyde River, rf	1200	(1208)*	(aBA1210)*
		Cape Sable Light	1228		
		Stoney Island, rw	1228		
	C	Barrington	1229	1231	dAF1044
		Near Clarks Harbour	1230		
	A	West Head, rw	1500		
		Cape Sable Light, 2r	1512		
		Villagedale, r	1514		
	C	Ingomar, rw	1514	(1511)*	(dAF1315)*
		East Beccaro	1515		
		Bear Point	1515		
		Point Joli, rw	1520		

## NOVA SCOTIA - FEBRUARY

DATE 1978	C,A,N CODE		ACTUAL TIME	FLIGHT ARR	ACTUAL
			OF EVENT	CALCULATED	ARR/DEP
			AST	AST	EST
	C	Newellton, rw, rh	1530	1515	dBA1328
<u>3</u>		NO EVENT		0853	aAF0841
<u>Fri</u>	A	The Hawk	1020		
	C	Baccaro, rw	1028		
		Cape Sable Light	1030	1028	aBA1016
		Stoney Island	1030		
		The Hawk	1030		
	A	Ingomar, b-30 sec, rh, rw	1212		
		Ingomar	1229		
		Shag Harbour	1229		
	C	Villagedale	1229	1228	dAF1041
		Middle E. Pubnico, rh	1230		
		Barrington, r-2 min., 2b	1230		
	A	Stoney Island	1255		
		Shag Harbour	1414		
		Doctors Cove, 2b	1415	1416	dBA1230
	C	Ingomar	1415		
		Cape Sable Light	1415		
		NO EVENT		(1441)*	(dBA1245)*
		NO EVENT		(1753)*	(aAF1755)*
	N	Villagedale	1955		
		Atwoods Brook, rw	1955		
	N	Northeast Point	2000		
		Atwoods Brook	2000		
<u>4</u>		Shag Harbour	0715		
<u>Sat</u>		NO EVENT		0856	aAF0844
		NO EVENT		(1207)	(aBA1209)
	C	Smithville, rh, 2b	1240	1235	dAF1048
	N	Ingomar	1415		
	C	Barrington, rg,rw,2b	1519	(1511)*	(dAF1315)*
<u>5</u>	C	Cape Sable Light	0855	0854	aAF0842
<u>Sun</u>	C	Cape Sable Light	1027	1032	aBA1020
	N	Cape Sable Light	1132		
		NO EVENT		1238	dAF1051
	C	Ingomar, r	1415	1417	dBA1230
		Clyde River, rw	1430		
		NO EVENT		(1441)*	(dBA1245)*
		NO EVENT		(1753)	(aAF1755)
<u>6</u>		Ingomar	1015		
<u>Mon</u>		Cape Sable Light	1020		
		Atwoods Brook	1020		

## NOVA SCOTIA - FEBRUARY

DATE 1978	C,A,N CODE		ACTUAL TIME	FLIGHT ARR	ACTUAL
			OF EVENT	CALCULATED	ARR/DEP
			AST	AST	TIME
					EST
	C	Barrington, rw	1020	1034	aBA1022
		Villagedale	1020		
		Stoney Island	1020		
		Newellton, rf	1020		
		NO EVENT		(1205)	(aBA1207)
		NO EVENT		(1513)	(dAF1317)
<u>7</u>	N	Barrington, rh,rw	1045	JFK AIRPORT CLOSED	
Tue	C	Port Saxon, rf	1430	(1441)*	(dBA1245)*
<u>8</u>	W	Stoney Island, rw	0100		
Wed		NO EVENT		1302	aBA1250
		Cape Sable Light, 2r, rd	1800		
		Bear Point	1800		
		Port Saxon	1800		
		Sluice Point, rh	1802		
	C	Morris Island	1802	(1753)*	(aAF1755)*
		Barrington Passage	1802		
		Middle East Pubnico,rw	1802		
		Barrington, rw	1802		
		Villagedale	1802		
		Northeast Point	1803		
	C	Barrington, r	1806	1801	dBA1614
		Port Saxon, r	1806		
		Villagedale	1825		
	C	Middle East Pubnico, rw	1825	1827	dBA1640
		Port Saxon	1825		
		Clyde River	1825		
<u>9</u>		NO EVENT		0707	aAF0655
Thu		NO EVENT		1019	aBA1007
		NO EVENT		1038	aAF1026
		NO EVENT		(1208)*	(aBA1210)*
	C	Cape Sable Light	1340		
		Ingomar, 2b	1342	1344	dAF1157
		Northeast Harbour	1345		
	A	Bear Point, 3b	1400		
		Cape Sable Light	1420		
	C	Shag Harbour, rh	1420	1420	dBA1233
		Ingomar, r			
		Port Saxon, rw	1420		
		NO EVENT		(1510)	(dAF1314)
	A	Ingomar, 6b - 15 sec apart, rh	1656		
		Bear Point	1700		
		Lower Woods Harbour, rd	1700		
	C	Barrington	1700	1659	dAF1512
		Clarks Harbour, r, 2b	1701		
		Northeast Point			

## NOVA SCOTIA - FEBRUARY

DATE 1978	C,A,N CODE		ACTUAL TIME	FLIGHT ARR	ACTUAL
			OF EVENT	CALCULATED	ARR/DEP
			AST	TIME	TIME
				AST	EST
	A	Cape Sable Light	1710		
	A	Northeast Point	1955		
<u>10</u>		NO EVENT		0857	aAF0845
<u>Fri</u>	A	Newellton	1030		
	C	Cape Sable Light	1040	1039	aBA1027
	A	Ingomar, ln,r like plane	1145		
		NO EVENT		1231	dAF1044
	C	Bear Point	1410	1418	dBA1231
		Ingomar, 6-8r	1415		
	A	Barrington, 2b	1416		
		NO EVENT		(1441)*	(dBA1245)*
		NO EVENT		(1753)*	(aAF1755)*
<u>11</u>	C	Cape Sable Light	0855	0854	aAF0842
<u>Sat</u>	A	Clarks Harbour, r	0905		
		NO EVENT		1041	aBA1029
		NO EVENT		(1208)*	(aBA1210)*
		Cape Sable Light,ln, r,2b	1237		
		Jordan Bay	1240		
	C	Villagedale	1240	1239	dAF1052
		Barrington	1240		
		Ingomar, r	1240		
	C	Cape Sable Light	1520	1515	dBA1328
	C	Villagedale	1522	(1514)	(dAF1318)
	A	Clarks Harbour, 2r	1615		
<u>12</u>		NO EVENT		0858	aAF0846
<u>Sun</u>	A	Cape Sable Light	1117		
		NO EVENT		1140	aBA1128
		Cape Sable Light	1224		
	C	Ingomar, rg,2b cr	1226		
		Shag Harbour	1228	1225	dAF1038
		Villagedale, ln r	1228		
	A	Ingomar, 2b,rh,rg	1255		
	N	Woods Harbour	1400		
		Northeast Point	1400		
	A	Cape Sable Light, 2b,r	1417		
		NO EVENT		(1441)*	(dBA1245)*
	C	Bear Point, 2b cr,rf,rh	1448	1448	dBA1301
		Barrington	1450		
	A	Cape Sable Light, 2b,r	1502		

## NOVA SCOTIA - FEBRUARY

DATE 1978	C,A,N CODE		ACTUAL TIME OF EVENT AST	FLIGHT ARR CALCULATED TIME AST	ACTUAL ARR/DEP TIME EST
16 Thu		NO EVENT		0906	aAF0854
	C	Wood Harbour, rw	1100	1106	aBA1054
		NO EVENT		(1208)*	(aBA1210)*
	C	Barrington, rw	1227	1229	dAF1042
		Ingomar, ln r	1227		
		Villagedale, rh	1455		
	C	Ingomar, ab,rh,rf,ln r	1457	1459	dBA1312
		Woods Harbour, rh,rf	1457		
		Barrington, rf, rh	1500		
		NO EVENT		(1521)	(dAF1325)
17 Fri		NO EVENT		0948	aAF0936
	C	Southside, rd	1030	1049	aBA1038
	A	Baccaro	1230		
		Whitehead Island, ln r, 2b	1230		
	A	Baccaro	1235		
		Ingomar	1243		
		Doctors Cove, rw,rh	1245		
		Barrington, rw	1245		
	C	Shag Harbour, 3r,rw	1245	1247	dAF1100
		Roseway, rh	1245		
		Villagedale, r,rw	1245		
		Lower Ohio	1245		
	A	Barrington, rh	1315		
	N	Stoney Island	1415		
		Port Saxon	1434		
		Ingomar	1435		
	A	Thomasville	1437		
		Barrington	1438		
		Barrington	1439		
		Villagedale	1439		
		Barrington Passage, rh	1440		
	C	Barrington, rf, rh	1440	1441	dBA1254
		Smithsville	1440		
		Lower Ohio	1442		
		Barrington, rf	1445		
		Shelburne	1445		
	C	Barrington W., rd,2b	1445	(1447)	(dBA1251)
		Wood Harbour, lr, ln	1445		
		Port Saxon, ln r	1451		
	A	Whitehead Island, 2b	1500		
	N	Baccaro, r	1525		
		NO EVENT		(1753)*	(aAF1755)*



## NOVA SCOTIA - FEBRUARY

DATE 1978	C,A,N CODE		ACTUAL TIME	FLIGHT ARR	ACTUAL	
			OF EVENT	CALCULATED	ARR/DEP	
			AST	TIME	TIME	
				AST	EST	
<u>18</u> Sat	C	Smithville	0855			
		Bear Point	0905	0905	aAF0853	
	A	Bear Point	0921			
		NO EVENT		1031	aBA1019	
	C	Clarks Harbour, 1a r	1220			
		Woods Harbour, r	1220			
		Centreville, 1a r	1220			
		Baccaro, r	1224	1224	dAF1037	
		Barrington, 2r	1225			
		Villagedale, r	1225			
		Ingomar, rw	1226			
		Baccaro, r	1228			
		A	Bear Point, rh	1230		
			Shag Harbour, 2b	1230		
		A	Barrington, rh, mirror shattered	1415		
	Clarks Harbour		1420			
	Wood Harbour, rw		1420			
	Villagedale, rw,rh		1425			
	Stoney Island, rh		1425			
	Clarks Harbour, 3b,r		1425			
	Baccaro, r		1428			
	Barrington, rw,r,no b		1428			
	C		Barrington, rw	1430	1431	dBA1244
			Jordan Falls, 2b	1430		
			Ingomar, rf	1430		
		Southside, rf	1430			
		Centreville, r	1430			
		Stoney Island	1430			
		Whitehead Island, 2b	1430			
	C	Port Saxon, rw	1520			
		Ingomar	1520	(1511)*	(dAF1315)*	
		Centreville, r	1520			
		Upper Clyde	1525			
N	Southside, r	1600				
	E. Lawrencetown, 9b, rw, rh	1607				
N	Upper Clyde River 1723					
<u>19</u> Sun	C	Ingomar	1030	1045	aBA1033	
		NO EVENT		1208	aAF1156	
	N	Ingomar, rh	1336			
	C	Villagedale	1430	1423	dBA1236	
		Ingomar	1435			
	C	Ingomar	1450	(1441)*	(dBA1245)*	
		E. Lawrence, 3b	1500			
	A	Baccaro, r	1525			

## NOVA SCOTIA - FEBRUARY

DATE 1978	C,A,N CODE		ACTUAL TIME	FLIGHT ARR	ACTUAL
			OF EVENT	CALCULATED	ARR/DEP
			AST	AST	TIME
					EST
	C	Baccaro	1530	1531	dAF1344
		Crowells	1530		
	N	Ingomar	1630		
		NO EVENT		(1753)*	(aAF1755)*
	N	Ingomar	1952		
<u>20</u>		NO EVENT		1010	aAF0958
<u>Mon</u>		NO EVENT		1034	aBA1022
		NO EVENT		(1224)	(aBA1226)
	A	Ingomar, rw	1240		
	C	Ingomar, rw	1334	1336	dAF1149
	A	Newellton, Jr	1340		
		Crowells	1414		
		Villagedale	1415		
	C	Ingomar, rw	1419	1420	dBA1233
		Lower Ohio, ln r	1422		
	C	Ingomar, rw	1525	(1518)	(dAF1322)
	A	Barrington	1537		
<u>21</u>		NO EVENT		0903	aAF0851
<u>Tue</u>		NO EVENT		1050	aBA1038
	C	Barrington, rf	1445	(1441)*	(dBA1245)*
		Bear Point, rd	1445		
		NO EVENT		1527	dAF1340
	C	Bear Point, r no b	1600	1548	dBA1401
<u>22</u>		Barrington	0902		
<u>Wed</u>		NO EVENT		0934	aAF0922
		NO EVENT		1120	aBA1108
	C	Barrington, rh	1250	1251	dAF1104
	N	Barrington, rw,rh	1346		
	A	Port Saxon, rh	1430		
		Villagedale, r	1450		
	C	Ingomar, 2b,rh	1453	1453	dBA1306
		Barrington, 2b	1455		
		NO EVENT		(1753)*	(aAF1755)*
<u>23</u>		NO EVENT		0851	aAF0839
<u>Thu</u>		NO EVENT		1027	aBA1015
	C	Ingomar, rh	1232	(1223)	(aBA1225)
	C	Ingomar, rh	1235	1231	dAF1044
	C	Ingomar	1418	1419	dBA1232
	A	Ingomar, rh	1430		
	A	Barrington, ln r	1445		
	C	Port Saxon	1515	(1511)	(dAF1315)
	N	Barrington, ln r	2304		

## NOVA SCOTIA - FEBRUARY

DATE 1978	C,A,N CODE		ACTUAL TIME	FLIGHT ARR	ACTUAL
			OF EVENT	CALCULATED	ARR/DEP
			AST	TIME	TIME
				AST	EST
<u>24</u> Fri	C	Stoney Island, rh	0915	0906	aAF0854
		NO EVENT		1015	aBA1003
	C	Northeast Point, 2b	1220		
		Villagedale	1220	1220	dAF1033
		Southside, rh	1220		
	N	Crowells, r	1315		
		Bear Point, 5 explosions	1315		
		NO EVENT		(1441)*	(dBA1245)*
	A	Barrington, r,rw, rh	1500		
		Villagedale, r	1515		
		Bear Point, 2b	1515		
	C	Ingomar, rw, rh	1516	1518	dBA1331
		Bear Point, 1b, 2b	1517		
		Shag Harbour, 3r	1520		
		Crowells, rh	1520		
		NO EVENT		(1753)*	(aAF1755)*
<u>25</u> Sat		NO EVENT		0855	aAF0843
		NO EVENT		1033	aBA1021
	C	Northeast Point	1220	(1208)*	(aBA1210)*
		Villagedale, rw, r	1225		
	C	Whitehead Island, 2b, r, 1b	1225	1230	dAF1043
		Atwood Brook, rw, rh	1227		
		Ingomar, rw	1230		
		NO EVENT		1450	dBA1303
		NO EVENT		(1511)*	(dAF1315)*
	N	Barrington, r, then b	1620		
		Brass Hill, r, then b	1620		
<u>26</u> Sun		NO EVENT		0850	aAF0838
		NO EVENT		1035	aBA1023
	N	Barrington	1130		
	C	Villagedale, r	1220	1223	dAF1036
	A	Ingomar, 2-3r	1244		
	N	Barrington Passage	1320		
	C	Ingomar, r	1416	1418	dBA1231
		Whitehead Island, 2b	1420		
	C	Barrington Passage	1445	(1441)*	(dBA1245)*
	N	Barrington Passage	1550		
	A	Barrington, 2b	1620		
		NO EVENT		(1753)*	(aAF1755)*
<u>27</u> Mon	N	Bear Point, rw	0750		
		Clarks Harbour	0855		
	C	The Hawk	0855	0852	aAF0840

## NOVA SCOTIA - FEBRUARY

DATE 1978	C,A,N CODE	PLACE OF EVENT	ACTUAL TIME OF EVENT	FLIGHT ARR CALCULATED TIME	ACTUAL ARR/DEP TIME
		Ingomar	0900		
		NO EVENT		1027	aBA1015
		NO EVENT		(1154)	(aBA1156)
	C	Ingomar, 3b	1222	1219	dAF1032
		Villagedale, r	1415		
		Ingomar, r	1420		
	C	Barrington Passage, ln, r,wr	1420	1419	dBA1232
		Barrington, ln popping sound, lb	1420		
	A	Northeast Point	1430		
	C	Crowell, 2 ln r	1520	(1513)	(dAF1317)
<u>28</u>		NO EVENT		0859	aAF0847
Tue		NO EVENT		1028	aBA1016
		NO EVENT		1232	dAF1045
		Cape Sable Light	1415		
		Bear Point, rf	1417		
	C	Ingomar, ln r,2b	1417	1418	dBA1231
		Barrington, 3b cr-5 mins.	1417		
		Villagedale ln r-5 mins.	1420		
		NO EVENT		(1441)*	(dBA1245)*
	N	Ingomar, r	1901		

## NOVA SCOTIA - MARCH

DATE 1978	C,A,N CODE	PLACE OF EVENT	ACTUAL TIME OF EVENT	FLIGHT ARR CALCULATED TIME	ACTUAL ARR/DEP TIME
<u>1</u>		NO EVENT		0859	aAF0847
Wed		Villagedale, rf	0922		
	C	Cape Sable Light	0922	0926	dAF0739
		Ingomar, rf,b,no r	0923		
		NO EVENT		1041	aBA1029
	C	Cape Sable Light	1222	1223	dAF1036
		Ingomar, r,rf	1224		
		NO EVENT		1427	dBA1240
		NO EVENT		(1753)*	(aAF1755)*
<u>2</u>		NO EVENT		0905	aAF0853
Thu		NO EVENT		1014	aBA1002
		NO EVENT		(1208)*	(aBA1210)*
		NO EVENT		1223	dAF1036
	C	The Hawk, r	1430		
		Barrington Passage	1430	1416	dBA1229
	A	The Hawk	1440	(1511)*	(dAF1315)*
<u>3</u>		NO EVENT		0906	aAF0854
Fri		NO EVENT		1035	aBA1023
	N	Clyde River	1115		
		NO EVENT		1230	dAF1043
	A	Seal Island	1410		
	C	Port Saxon	1430	1437	dBA1250
	C	The Hawk	1440	(1441)*	(dBA1245)*
		NO EVENT		(1753)*	(aAF1755)*
<u>4</u>		NO EVENT		0900	aAF0848
Sat		NO EVENT		1027	aBA1015
		NO EVENT		(1208)*	(aBA1210)*
		NO EVENT		1310	dAF1123
		NO EVENT		1431	dBA1244
		NO EVENT		(1511)*	(dBA1315)*
<u>5</u>		NO EVENT		0852	aAF0840
Sun		NO EVENT		1054	aBA1042
		NO EVENT		1228	dAF1041
		NO EVENT		1429	dBA1242
		NO EVENT		(1441)*	(dBA1245)*
		NO EVENT		(1753)*	(aAF1755)*
<u>6</u>		NO EVENT		1037	aBA1025
Mon		NO EVENT		1109	aAF1057
		NO EVENT		(1208)*	(aBA1210)*
		NO EVENT		1414	dAF1227
		NO EVENT		1428	dBA1241
		NO EVENT		(1511)*	(dBA1315)*
<u>7</u>		NO EVENT		0856	aAF0844
Tue		NO EVENT		1017	aBA1005

## NOVA SCOTIA - MARCH

DATE 1978	C,A,N CODE	PLACE OF EVENT	ACTUAL TIME OF EVENT	FLIGHT ARR CALCULATED TIME	ACTUAL ARR/DEP TIME
	C	Stoney Island Ingomar, r	1220 1220	1223	dAF1036
	A	The Hawk, r	1230		
	A	Stoney Island, r	1240		
	C	Cape Sable Light Port Saxon, r, rf Ingomar The Hawk, r Whitehead Island, 3-4r	1410 1415 1415 1415 1420	1416	dBA1229
	C	Cape Sable Light Villagedale Baccaro Crowells	1445 1445 1445 1450	(1441)*	(dBA1245)*
<u>8</u> Wed		NO EVENT		0905	aAF0853
		NO EVENT		1044	aBA1032
	C	Clan Point, nr Ingomar NO EVENT NO EVENT	1400	1345 1731 (1753)*	dAF1158 dBA1544 (aAF1755)*
	N	Whitehead Island, 4-5b	2018		
<u>9</u> Thu		NO EVENT		0930	aAF0918
		NO EVENT		1035	aBA1023
		NO EVENT		(1208)*	(aBA1210)*
	C	Ingomar Cape Sable Light Northeast Point, rf	1245 1246 1248	1246	dAF1059
	C	Cape Sable Light	1410	1414	dBA1227
	C	Oak Park, ln r Doctors Cove, ln r	1515 1520	(1511)*	(dAF1315)*
	A	Doctors Cove	1525		
<u>10</u> Fri		NO EVENT		0909	aAF0857
		NO EVENT		1045	aBA1033
	N	Ingomar	1200		
	A	Whitehead Island	1219		
	C	Cape Sable Light	1225	1237	dAF1050
	N	Northeast Point, rh	1330		
	C	Cape Sable Light	1410	1423	dBA1236
	A	Cape Sable Light	1435		
	N	Cape Sable Light	1520		

## NOVA SCOTIA - MARCH

DATE 1978	C,A,N CODE	PLACE OF EVENT	ACTUAL TIME OF EVENT	FLIGHT ARR CALCULATED TIME	ACTUAL ARR/DEP TIME
		NO EVENT		(1753)*	(aAF1755)*
<u>11</u> Sat	C	Barrington	0914	0901	aAF0849
		NO EVENT		1026	aBA1014
	C	Villagedale	1215	(1208)*	(aBA1210)*
		Ingomar	1227		
	C	Whitehead Island	1230	1413	dAF1042
		Barrington, rh	1230		
		Wood Harbour, rf	1230		
	N	Barrington Passage, rv	1310		
		Whitehead Island, 3b cr	1410		
		Barrington, 2-3b in cr	1413-1415		
	C	Barrington Passage, in r	1413	1413	dBA1226
		Ingomar, 2b	1414		
		Villagedale	1415		
		Barrington	1415		
	A	Northeast Point	1500		
		Wood Harbour	1520		
	C	Whitehead Island	1520	(1511)*	(dAF1315)*
		Barrington, rv	1521		
		Ingomar, rh	1523		
<u>12</u> Sun		NO EVENT		0856	aAF0844
		NO EVENT		1016	aBA1004
	A	Wood Harbour	1225		
		Wood Harbour	1230		
	C	Northeast Point	1230	1228	dAF1041
		Centreville	1230		
	C	Boat, 42°55'N, 65°36.5'W	1402	1413	dBA1226
		NO EVENT		(1441)*	(dBA1245)*
		NO EVENT		(1753)*	(aAF1755)*
<u>13</u> Mon		Boat, 42°55'N, 64°58'W	0859		
		Cape Sable Light	0900		
	C	Baccaro, rh, 2b	0900	0904	aAF0852
		Clarks Harbour, rh	0900		
		Centreville	0900		
	C	Boat, of morning	1014	1019	aBA1007
	C	Boat, of morning	1208	(1208)*	(aBA1210)*
		NO EVENT		1229	dAF1042
	C	Cape Sable Light	1422	1421	dBA1234
	C	Cape Sable Light	1525	(1511)*	(dAF1315)*
	N	Cape Sable Light	1803		

## NOVA SCOTIA - MARCH

DATE 1978	C,A,N CODE	PLACE OF EVENT	ACTUAL TIME OF EVENT	FLIGHT ARR CALCULATED TIME	ACTUAL ARR/DEP TIME
<u>14</u>	N	Bear Point, rh, no b	0700		
Tue	C	Boat, 42°47.5'N, 65°30'W	0859	0909	aAF0857
		NO EVENT		1030	aBA1018
		NO EVENT		1228	(dAF1041)
		NO EVENT		1418	dBA1231
		NO EVENT		(1441)*	(dBA1245)*
<u>15</u>		NO EVENT		0904	aAF0852
Wed		NO EVENT		1029	aBA1017
		NO EVENT		1232	dAF1045
		NO EVENT		1420	dBA1233
	C	Boat of 14th	1757	(1753)*	(aAF1755)*
<u>16</u>		NO EVENT		0908	aAF0856
Thu		NO EVENT		1027	aBA1015
		NO EVENT		(1208)*	(aBA1210)*
		NO EVENT		1320	dAF1133
		NO EVENT		(1511)*	(dAF1315)*
<u>17</u>		NO EVENT		1050	aBA1038
Fri		NO EVENT		1126	dBA0939
		NO EVENT		1202	aAF1150
		NO EVENT		1421	dBA1235
	C	Bear Point	~1500	(1441)*	(dBA1245)*
	C	Cape Sable Light	1750	(1753)*	(aAF1755)*
<u>18</u>		NO EVENT		0858	aAF0846
Sat		NO EVENT		1025	aBA1013
		NO EVENT		(1208)*	(aBA1210)*
	C	Cape Sable Light	1238	1236	dAF1049
	C	Cape Sable Light Stoney Island	1430 1430	1426	dBA1239
	C	Barrington, rw, r	1526	(1515)*	(dBA1315)*
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BA - arrival time change (-60 minutes)					
<u>19</u>		NO EVENT		0853	aAF0841
Sun		NO EVENT		0937	aBA0925
		NO EVENT		1239	dAF1052
		NO EVENT		1416	dBA1229
	C	Stoney Island	1500	(1441)*	(dBA1245)*
		NO EVENT		(1753)*	(aAF1755)*
<u>20</u>		NO EVENT		0900	aAF0848
Mon		NO EVENT		1021	aBA1009
		NO EVENT		(1108)*	(aBA1110)*



## NOVA SCOTIA - MARCH

DATE 1978	C,A,N CODE	PLACE OF EVENT	ACTUAL TIME OF EVENT	FLIGHT ARR CALCULATED TIME	ACTUAL ARR/DEP TIME
	C	NO EVENT Barrington	1410	1228 1414	dAF1041 dBA1227
		NO EVENT		(1511)*	(dBA1315)*
<u>21</u> Tue		NO EVENT		1130	aAF1118
		NO EVENT		1338	aBA1326
		NO EVENT		(1441)*	(dBA1245)*
		NO EVENT		1514	dAF1327
		NO EVENT		1645	dBA1458
<u>22</u> Wed		NO EVENT		0904	aAF0852
		NO EVENT		0941	aBA0929
		NO EVENT		1218	dAF1031
		NO EVENT		1416	dBA1229
		NO EVENT		(1753)*	(aAF1755)*
<u>23</u> Thu	C	NO EVENT Whitehead Island	0930	0853 0924	aAF0841 aBA0912
		NO EVENT		(1108)*	(aBA1110)*
		NO EVENT		1227	dAF1040
		NO EVENT		1413	dBA1226
		NO EVENT		(1511)*	(dAF1315)*
<u>24</u> Fri	N	NO EVENT Northeast Point	1145-1200	0851	aAF0839
	C	Bear Point	1210		
	C	Coffinscroft Bear Point	1220 1230	1228	dAF1041
		NO EVENT		(1441)*	(dBA1245)*
		NO EVENT		(1753)*	(aAF1755)*
<u>25</u> Sat		NO EVENT		0854	aAF0842
		NO EVENT		0921	aBA0909
		NO EVENT		(1108)*	(aBA1110)*
	C	Bear Point, r Barrington Passage	1410 1410	1411	dBA1224
		NO EVENT		(1511)*	(dBA1315)*
<u>26</u> Sun		NO EVENT		0846	aAF0834
		NO EVENT		0910	aBA0858
		NO EVENT		1220	dAF1033
	N	Ingomar, 3b	1334		
	A	Barrington Passage Barrington	1410 1410		

## NOVA SCOTIA - MARCH

DATE 1978	C,A,N CODE	PLACE OF EVENT	ACTUAL TIME OF EVENT	FLIGHT ARR CALCULATED TIME	ACTUAL ARR/DEP TIME
	C	Coffinscroft Barrington	1420 1421	1422	dBA1235
	C	Ingomar, 3b	1428	(1441)*	(dBA1245)*
	N	Stoney Island	1645		
		NO EVENT		(1753)*	(aAF1755)*
	N	Cape Sable Light, 2r	1835		
<u>27</u> Mon		NO EVENT		(1108)*	(aBA1110)*
		NO EVENT		1234	aAF1222
		NO EVENT		1353	aBA1341
		NO EVENT		(1511)*	(dBA1315)*
		NO EVENT		1619	dAF1432
		NO EVENT		1711	dBA1524
<u>28</u> Tue		NO EVENT		0851	aAF0839
		NO EVENT		0932	aBA0920
		NO EVENT		1225	dAF1038
	C	Barrington Passage	1414	1414	dBA1227
		NO EVENT		(1443)*	(dBA1245)*
<u>29</u> Wed		NO EVENT		0902	aAF0850
		NO EVENT		0947	aBA0935
	C	Baccaro	1245	1242	dAF1055
		Cape Sable Light	1410		
		Barrington, r	1410		
	C	Barrington Passage, 3b,r	1410	1413	dBA1226
		Clyde River	1410		
		Ingomar	1410		
		NO EVENT		(1753)*	(aAF1755)*
<u>30</u> Thu		NO EVENT		0853	aAF0841
		NO EVENT		(1108)*	(aBA1110)*
		NO EVENT		1219	aBA1207
		NO EVENT		1222	dAF1035
	N	The Hawk, v	1255		
		NO EVENT		(1511)*	(dAF1315)*
		NO EVENT		1547	dBA1400
<u>31</u> Fri		NO EVENT		0847	aAF0835
		NO EVENT		0914	aBA0902
	C	Ingomar	1236	1229	dAF1042
		Ingomar	1238		
	C	Cape Sable Light	1415	1415	dBA1228
		NO EVENT		(1441)*	(dBA1245)*
		NO EVENT		(1753)*	(aAF1755)*

## NOVA SCOTIA - APRIL

DATE 1978	C,A,N CODE	PLACE OF EVENT	ACTUAL TIME OF EVENT AST	CALCULATED TIME AST	ACTUAL ARR/DEP TIME EST
<u>1</u> Sat		NO EVENT		0852	aAF0840
		NO EVENT		1007	aBA0955
		NO EVENT		(1008)*	(aBA1110)*
	C	Bear Point	= 1400	1233	dAF1046
		NO EVENT		1424	dBA1237
				(1511)*	(dAF1315)*
<u>2</u> Sun		NO EVENT		0750	aAF0738
		NO EVENT		0916	aBA0904
	C	Bear Point	= 1400	1421	dBA1234
		NO EVENT		(1441)*	(dBA1245)*
		NO EVENT		1508	dAF1321
		NO EVENT		(1653)*	(aAF1655)*
<u>3</u> Mon		NO EVENT		0752	aAF0740
		NO EVENT		0944	aBA0932
	A	Bear Point, rh	1010		
		NO EVENT		(1108)*	(aBA1110)*
	N	Barrington, 3b	1200		
	N	Bear Point	1300		
		NO EVENT		1410	dBA1223
	C	Cape Sable Light, 2b, cr 1500		1506	dAF1319
		NO EVENT		(1511)*	(dAF1315)*
	N	Barrington Passage, 2b 1620			
<u>4</u> Tue		NO EVENT		0757	aAF0745
		NO EVENT		0918	aBA0906
		NO EVENT		1418	dBA1231
		NO EVENT		(1441)*	(dBA1245)*
		NO EVENT		1626	dAF1439
<u>5</u> Wed		NO EVENT		0749	aAF0737
		NO EVENT		0928	aBA0916
		NO EVENT		1416	dBA1229
		NO EVENT		1456	dAF1309
		NO EVENT		(1653)*	(aAF1655)*
<u>6</u> Thu		NO EVENT		0831	aAF0819
		NO EVENT		1001	aBA0949
		NO EVENT		(1108)*	(aBA1110)*
	C	Cape Sable Light	1427	1421	dBA1235
		NO EVENT		(1511)*	(dAF1315)*
		NO EVENT		0027	dAF2240
<u>7</u> Fri		NO EVENT		0759	aAF0747
		NO EVENT		0946	aBA0934
		NO EVENT		(1441)*	(dBA1245)*
		NO EVENT		1444	dBA1257
	C	Ingomar, rh	1500	1510	dAF1323
		NO EVENT		(1653)*	(aAF1655)*
<u>8</u> Sat		NO EVENT		0744	aAF0732
		NO EVENT		0911	aBA0859

## NOVA SCOTIA - APRIL

DATE 1978	C,A,N CODE	PLACE OF EVENT	ACTUAL TIME	CALCULATED	ACTUAL
			OF EVENT	TIME	ARR/DEP
			AST	AST	TIME
					EST
		NO EVENT		(1108)*	(aBA1110)*
		NO EVENT		1421	dBA1234
		NO EVENT		1504	dAF1317
	A	The Hawk	1500-1600		
<u>9</u>		NO EVENT		0744	aAF0732
Sun	C	Lower Ohio	0925	0917	aBA0905
		NO EVENT		1420	dBA1233
		NO EVENT		(1441)*	(dBA1245)*
		Cape Sable Light	1500		
		Newellton, rh	1505	1503	dAF1316
		The Hawk, rh	1505		
		NO EVENT		(1653)*	(aAF1655)*
<u>10</u>		NO EVENT		0756	aAF0744
Mon	A	Browns Bank	0845		
	C	Lower Ohio	0915	0911	aBA0859
		NO EVENT		(1108)*	(aBA1110)*
	C	Barrington	1415	1413	dBA1226
		NO EVENT		1502	dAF1315
		NO EVENT		(1511)*	(dAF1315)*
<u>11</u>		Lower Ohio, In r	0800		
Tue	C	Newellton, rh	0800	0755	aAF0743
		Clyde River	0925		
	C	Barrington	0925	0926	aBA0914
	A	Cape Sable Light	0950		
		Hebron, Yarn. Co.	1000		
		NO EVENT		1415	dBA1228
		NO EVENT		(1441)*	(dBA1245)*
		NO EVENT		1501	dAF1314
<u>12</u>		NO EVENT		0751	aAF0739
Wed		NO EVENT		0906	aBA0854
	N	Northeast Point, v	1330		
	C	Crowells	1415	1416	dBA1229
		NO EVENT		1505	dAF1318
	C	Northeast Harbour	1650		
		Barrington, 2b	1652	(1653)*	(aAF1655)*
<u>13</u>		NO EVENT		0753	aAF0741
Thu		NO EVENT		0915	aBA0903
	C	Ingomar, rh	1105	(1108)*	(aBA1110)*
	C	Northeast Harbour	1415	1420	dBA1233
		NO EVENT		1512	dAF1325
		NO EVENT		(1511)*	(dAF1315)*

## NOVA SCOTIA - APRIL

DATE 1978	C,A,N CODE	PLACE OF EVENT	ACTUAL TIME	CALCULATED	ACTUAL
			OF EVENT AST	TIME AST	ARR/DEP TIME EST
	N	Hubbards, r	evening		
<u>14</u> Fri	C	Cape Sable Light	0805	0802	aAF0750
		NO EVENT		0919	aBA0907
		NO EVENT		1418	dBA1231
		NO EVENT		(1441)*	(dBA1245)*
	C	Northeast Point	1500	1459	dAF1312
		NO EVENT		(1653)*	(aAF1655)*
<u>15</u> Sat		NO EVENT		0749	aAF0737
		NO EVENT		0913	aBA0901
		NO EVENT		(1108)*	(aBA1110)*
	A	Northeast Point	1400		
	C	Coffinscroft	1415		
		Centreville	1420	1414	dBA1227
	A	Northeast Point	1430		
	A	Crowells	1445		
		Cape Sable Light	1457		
		Northeast Point	1500		
	C	Southside	1500	1459	dAF1312
		Centreville, 2b	1500		
		Newellton	1500		
	C	Newellton	1504	(1511)*	(dAF1315)*
	A	Coffinscroft	1530		
		Barrington, r	1530		
	N	Cape Sable Light	1725		
<u>16</u> Sun		NO EVENT		0756	aAF0744
		NO EVENT		0911	aBA0859
		NO EVENT		1427	dBA1240
		NO EVENT		(1441)*	(dBA1245)*
		NO EVENT		1457	dAF1310
		NO EVENT		(1653)*	(aAF1655)*
<u>17</u> Mon		NO EVENT		0753	aAF0741
	C	Brown's Bank	0900	0920	aBA0908
		NO EVENT		(1108)*	(aBA1110)*
		NO EVENT		1418	dBA1231
	C	Cape Sable Light	1458	1456	dAF1309
		NO EVENT		(1511)*	(dAF1315)*
<u>18</u> Tue		NO EVENT		0759	aAF0747
		NO EVENT		0935	aBA0923

## NOVA SCOTIA - APRIL

DATE 1978	C,A,N CODE	PLACE OF EVENT	ACTUAL TIME	CALCULATED	ACTUAL
			OF EVENT	TIME	ARR/DEP
			AST	AST	TIME
					EST
	A	Boylston	1400		
		NO EVENT		1422	dBAl235
		NO EVENT		(1441)*	(dBAl245)*
		NO EVENT		1505	dAF1318
<u>19</u>		NO EVENT		0806	aAF0754
<u>Wed</u>		NO EVENT		0927	aBA0915
	N	Boylston, mb	1400		
	C	Crowells	1500	1510	dAF1323
		Coffinscroft, ln r	1510		
	C	Cape Sable Light	1645	1647	dBAl500
		Crowells	1648		
	C	Cape Sable Light, 2B	1705	(1653)*	(aAF1655)*
<u>20</u>		NO EVENT		0820	aAF0808
<u>Thu</u>		NO EVENT		0922	aBA0910
		NO EVENT		(1108)*	(aBA1110)*
		NO EVENT		1416	dBAl229
		NO EVENT		1502	dAF1315
		NO EVENT		(1511)*	(dAF1315)*
	N	Boylston (like gunshots)	evening		
<u>21</u>		NO EVENT		0834	aAF0822
<u>Fri</u>		NO EVENT		0914	aBA0902
		NO EVENT		1418	dBAl231
	C	Cape Sable Light	1455	(1441)*	(dBAl245)*
	C	Newellton	1504	1507	dAF1320
		NO EVENT		(1653)*	(aAF1655)*
<u>22</u>		NO EVENT		0752	aAF0740
<u>Sat</u>		NO EVENT		(1108)*	(aBA1110)*
		NO EVENT		1352	aBA1340
	C	Baccaro, ln r	1500		
		Cape Sable Light, 2r, rd	1500	1459	dAF1312
	C	Clarks Harbour, ln r,rv	1504		
		Barrington, rv	1505	(1511)*	(dAF1315)*
		NO EVENT		1609	dBAl422
	N	Barrington	1650		
	N	Barrington, rv, rf	1705		
		Barrington, ln r	1710		
	A	Cape Sable Light, 3b	1710		

## NOVA SCOTIA - APRIL

DATE 1978	C,A,N CODE	PLACE OF EVENT	ACTUAL TIME	CALCULATED	ACTUAL
			OF EVENT	TIME	ARR/DEP
			AST	AST	TIME
					EST
		Clarks Harbour, 2b	1710		
	N	Northwest Harbour, rh The Hawk, rh	1715 1715		
<u>23</u> Sun	C	NO EVENT Liverpool NO EVENT	0800	0750 0805 0916	aAF0738 aBA0753 aBA0904
	C	Cape Sable Light, 2b Baccaro Ingomar	1410 1415 1417	1414	dBA1227
	N	NO EVENT NO EVENT Crowells, 3b, rd, rw NO EVENT	1550	(1441)* 1500 (1653)*	(dBA1245)* dAF1313 (aAF1655)*
<u>24</u> Mon		NO EVENT NO EVENT		0754 0914	aAF0742 aBA0902
	C	Barrington	1010	1008	aBA0821
	C	Cape Sable Light	1115	(1108)*	(aBA1110)*
	C	Shag Harbour, 4b	1410	1419	dBA1232
	A	Northwest Harbour, several booms	1430-1500		
	C	Crowells Coffinscroft	1457 1457	1451	dAF1304
		NO EVENT		(1511)*	(dAF1315)*
		Coffinscroft	1527		
	A	Northeast Harbour, rd, (twice) Ingomar, rw	1530 1530		
<u>25</u> Tue		NO EVENT NO EVENT NO EVENT NO EVENT		0804 0919 1412 (1441)*	aAF0752 aBA0907 dBA1225 (dBA1245)*
	C	Newellton, ln r Ingomar, mb, rw	1500 1507	1503	dAF1316
	A	Barrington, ln r, rw	1510		
<u>26</u> Wed		NO EVENT Cape Sable Light NO EVENT	0910	0806 0927	aAF0754 aBA0915
	C	Clyde River	1435	1428	dBA1241

## NOVA SCOTIA - APRIL

DATE 1978	C,A,N CODE	PLACE OF EVENT	ACTUAL TIME OF EVENT AST	CALCULATED TIME AST	ACTUAL ARR/DEP TIME EST
		NO EVENT		1503	dAF1316
		NO EVENT		(1653)*	(aAF1655)*
<u>27</u>		NO EVENT		0753	aAF0741
Thu	C	Cape Sable Light	0912	0912	aBA0900
		NO EVENT		(1108)*	(aBA1110)*
		NO EVENT		1423	dBA1236
		NO EVENT		1505	dAF1318
		NO EVENT		(1511)*	(dAF1215)*
<u>28</u>		NO EVENT		0757	aAF0745
Fri		NO EVENT		0919	aBA0907
		NO EVENT		1420	dBA1233
		NO EVENT		(1441)*	(dBA1245)*
	C	Port Clyde, rh,rg	1500	1459	dAF1312
		Coffinscroft, rw	1504		
		NO EVENT		(1653)*	(aAF1655)*
<u>29</u>		NO EVENT		0751	aAF0739
Sat		NO EVENT		0922	aBA0910
		NO EVENT		(1108)*	(aBA1110)*
	C	Barrington,4r(1 sec apart)	1425	1423	dBA1236
	C	Crowells, 2b	1450	1458	dAF1311
		NO EVENT		(1511)*	(dAF1315)*
	A	Crowells, 2r,2b,rd	1600		
				Atlantic Daylight Time	Eastern Daylight Time
<u>30</u>		NO EVENT		0856	aAF0844
Sun		NO EVENT		1033	aBA1021
		NO EVENT		1415	dBA1228
		NO EVENT		(1441)*	(dBA1245)*
		NO EVENT		1502	dAF1315
		NO EVENT		(1753)*	(aAF1755)*



## NOVA SCOTIA - MAY

DATE 1978	C,A,N CODE	PLACE OF EVENT	ACTUAL TIME OF EVENT ADT	CALCULATED TIME ADT	ACTUAL ARR/DEP TIME EST
<u>1</u> Mon		NO EVENT		0852	aAF0840
		NO EVENT		1014	aBA1002
		NO EVENT		(1208)*	(aBA1210)*
		NO EVENT		1417	dBA1230
		NO EVENT		1502	dAF1315
		NO EVENT		(1511)*	(dAF1315)*
<u>2</u> Tue	N	Bear Point	0650		
		NO EVENT		0849	aAF0837
		NO EVENT		1401	aBA1349
	C	The Hawk, rd,rf,v	1435	(1441)*	(dBA1245)*
	C	Crowells, 3b,l sec,3b	1455	1503	dAF1316
		NO EVENT		1733	dBA1546
<u>3</u> Wed	C	Cape Sable Light	0903	0853	aAF0841
	A	Baccaro Light Station	0910		
		NO EVENT		1013	aBA1001
	C	Coffinscroft	1417	1417	dBA1230
	A	Barrington, mb	1514		
	C	Barrington, 3b,rw	1532	1530	dAF1343
		Crowells, 3b	1535		
	N	The Hawk, r	1645		
		NO EVENT		(1753)*	(aAF1755)*
<u>4</u> Thu		NO EVENT		0853	aAF0841
		NO EVENT		1016	aBA1004
		NO EVENT		(1208)*	(aBA1210)*
	C	Cape Sable Light, 2b	1415	1417	dBA1230
		Barrington, 3r,rw	1419		
	A	Baccaro	1500		
	C	Barrington, rf	1512	1510	dAF1323
		Coffinscroft, rh,r	1512		
		Barrington, 4b	1513		
		Shag Harbour, 2b	1514		
	C	Northeast Harbour, r	1515	(1511)*	(dAF1315)*
		Newellton, r	1515		
		Barrington Passage	1515		
		Baccaro	1515		
<u>5</u> Fri		NO EVENT		0849	aAF0837
		NO EVENT		1018	aBA1006
	N	Northeast Point	1100		
	C	Cape Sable Light	1410	1422	dBA1235
		NO EVENT		(1441)*	(dBA1245)*
	C	Southside	1500	1501	dAF1314

## NOVA SCOTIA - MAY

DATE 1978	C,A,N CODE	PLACE OF EVENT	ACTUAL TIME OF EVENT ADT	CALCULATED TIME ADT	ACTUAL ARR/DEP TIME EST
	N	Southside NO EVENT	1600	(1753)*	(aAF1755)*
<u>6</u> Sat		NO EVENT		0850	aAF0838
		NO EVENT		1030	aBA1018
		NO EVENT		(1208)*	(aBA1210)*
	N	Bear Point	1340		
	C	Ingomar	1420	1418	dBA1231
	A	Crowells, 2b	1443		
		Southside	=1500		
	C	Port Saxon	1505	1507	dAF1320
		Ingomar, 2b,rh	1505		
	C	Crowells, 2b,rd,rw	1515	(1511)*	(dAF1315)*
		Bear Point, 2b	1520		
	N	Ingomar	1550		
		Southside, rw,rd	=1600		
<u>7</u> Sun		NO EVENT		0847	aAF0835
		NO EVENT		1007	aBA0955
		NO EVENT		1418	dBA1231
		NO EVENT		(1441)*	(dBA1245)*
	A	The Hawk	1500		
		NO EVENT		1537	dAF1350
		NO EVENT		(1753)*	(aAF1755)*
<u>8</u> Mon	N	Newellton, rh	0900		
		NO EVENT		0933	aAF0921
		NO EVENT		1020	aBA1008
	N	Ingomar, rw	1102		
		NO EVENT		(1208)*	(aBA1210)*
		NO EVENT		1454	dBA1311
		NO EVENT		1458	aAF1442
		NO EVENT		(1511)*	(dAF1315)*
		NO EVENT		1522	dAF1335
<u>9</u> Tue	A	The Hawk	1015		
		NO EVENT		0845	aAF0833
		NO EVENT		1031	dAF0844
		NO EVENT		1100	aBA1048
		NO EVENT		(1441)*	(dBA1245)*
		NO EVENT		1507	dAF1320
		NO EVENT		1705	dBA1518
<u>10</u> Wed		NO EVENT		0847	aAF0835
		NO EVENT		1011	aBA0959
		NO EVENT		1420	dBA1233
		NO EVENT		1501	dAF1314
		NO EVENT		(1753)*	(aAF1755)*

## NOVA SCOTIA - MAY

DATE 1978	C.A.N CODE	PLACE OF EVENT	ACTUAL TIME	CALCULATED	ACTUAL
			OF EVENT	TIME	ARR/DEP
			ADT	ADT	TIME
					EST
<u>11</u>		NO EVENT		0844	aAF0832
Thu		NO EVENT		1012	aBA1000
		NO EVENT		(1208)*	(aBA1210)*
		NO EVENT		1418	dBA1231
		NO EVENT		1502	dAF1315
		NO EVENT		(1511)*	(dAF1315)*
	N	Ingomar, rv	1555		
<u>12</u>		NO EVENT		0856	aAF0844
Fri		Shag Harbour, rh,v	1020		
	C	Bear Point	1020	1026	aBA1004
		Cape Sable Light	1020		
		Shag Harbour	1022		
	A	Wood Harbour	1030		
	N	Cape Sable Light	1050		
		Intervale, Guys. Co.	1100		
		NO EVENT		1422	dBA1235
		NO EVENT		(1441)*	(dBA1245)*
	C	Cape Sable Light	1518	1518	dAF1331
		Cape Sable Light	1520		
		NO EVENT		(1753)*	(aAF1755)*
	A	Cape Sable Light	1815		
		Northeast Harbour, r only	1815		
<u>13</u>	C	Cape Sable Light, 2b	0905	0856	aAF0844
Sat	C	Cape Sable Light, 2b	1020	1024	aBA1012
		NO EVENT		(1208)*	(aBA1210)*
		NO EVENT		1439	dBA1252
		NO EVENT		1508	dAF1321
		NO EVENT		(1511)*	(dAF1315)*
	N	Brass Hill	1828		
<u>14</u>		NO EVENT		0853	aAF0841
Sun		NO EVENT		1020	aBA1008
		NO EVENT		(1441)*	(dBA1245)*
	C	Cape Sable Light, 3b	1448	1447	dBA1300
	A	Cape Sable Light, 2b	1455		
		NO EVENT		1509	dAF1322
		NO EVENT		(1753)*	(aAF1755)*
<u>15</u>	N	Northeast Point	0605		
Mon		NO EVENT		0859	aAF0847
		NO EVENT		1035	aBA1023

## NOVA SCOTIA - MAY

DATE 1978	C,A,N CODE	PLACE OF EVENT	ACTUAL TIME OF EVENT ADT	CALCULATED TIME ADT	ACTUAL ARR/DEP TIME EST
		NO EVENT		(1208)*	(aBA1210)*
		NO EVENT		1505	dAF1318
		NO EVENT		(1511)*	(dAF1315)*
		NO EVENT		1654	dBA1507
<u>16</u>		NO EVENT		0903	aAF0851
Tue		NO EVENT		1020	aBA1008
	C	Crowells, 2b	1432	1429	dBA1242
		NO EVENT		(1441)*	(dBA1245)*
		NO EVENT		1527	dAF1340
	N	Bear Point, v	=1930		
<u>17</u>		NO EVENT		0857	aAF0845
Wed		NO EVENT		1013	aBA1001
		NO EVENT		1420	dBA1233
		NO EVENT		1511	dAF1324
	N	Charlesville, rh	1615		
		NO EVENT		(1753)*	(aAF1755)*
<u>18</u>		West Head	0845	0900	aAF0848
Thu		NO EVENT		(1208)*	(aBA1210)*
		NO EVENT		1259	aBA1247
		Baccaro	1400-1600		
		NO EVENT		(1511)*	(dAF1315)*
		NO EVENT		1530	dAF1343
	A	Charlesville, rv	1610		
		NO EVENT		1632	dBA1445
<u>19</u>		NO EVENT		0849	aAF0837
Fri		NO EVENT		1019	aBA1007
		NO EVENT		1413	dBA1226
		NO EVENT		(1441)*	(dBA1245)*
		NO EVENT		1505	dAF1318
		NO EVENT		(1753)*	(aAF1755)*
<u>20</u>		Cape Sable Light	0906	0902	aAF0850
Sat		NO EVENT		1023	aBA1011
		NO EVENT		(1208)*	(aBA1210)*
		NO EVENT		1415	dBA1228
		NO EVENT		1458	dAF1311
		NO EVENT		(1511)*	(dAF1315)*
<u>21</u>		NO EVENT		0856	aAF0844
Sun		Middleton, 2b,rv	1035	1023	aBA1011
		NO EVENT		1411	dBA1224
		NO EVENT		(1441)*	(dBA1245)*
		NO EVENT		1505	dAF1318
	C	Middleton	1750		
				(1753)*	(aAF1755)*

## NOVA SCOTIA - MAY

DATE 1978	C,A,W CODE	PLACE OF EVENT	ACTUAL TIME	CALCULATED	ACTUAL
			OF EVENT	TIME	ARR/DEP
			ADT	ADT	TIME
					EST
<u>22</u>		NO EVENT		0911	aAF0839
Mon		NO EVENT		1044	aBA1032
	A	Barrington	1102		
		Newellton	1102		
	A	Brass Hill, 2b	1130		
		NO EVENT		(1208)*	(aBA1210)*
		NO EVENT		1420	dBA1233
		NO EVENT		1457	dAF1310
		NO EVENT		(1511)*	(dAF1315)*
<u>23</u>	N	Southside	0815		
Tue		NO EVENT		0852	aAF0840
		NO EVENT		1004	aBA0952
		NO EVENT		1413	dBA1226
		NO EVENT		(1441)*	(dBA1245)*
	C	Northeast Harbour, rh	1505	1508	dAF1321
<u>24</u>		NO EVENT		0850	aAF0838
Wed		NO EVENT		1023	aBA1011
		NO EVENT		1428	dBA1241
	C	Ingomar	1505	1504	dAF1317
		Barrington, rh	1510		
		NO EVENT		(1753)*	(aAF1755)*
<u>25</u>		NO EVENT		0849	aAF0837
Thu		NO EVENT		1042	aBA1030
		NO EVENT		(1208)*	(aBA1210)*
		NO EVENT		1417	dBA1230
		NO EVENT		1459	dAF1312
		NO EVENT		(1511)*	(dAF1315)*
<u>26</u>		NO EVENT		0856	aAF0844
Fri		NO EVENT		1018	aBA1006
		NO EVENT		1402	aBA1350
		NO EVENT		1431	dBA1244
		NO EVENT		(1441)*	(dBA1245)*
		NO EVENT		(1753)*	(aAF1755)*
		NO EVENT		1833	dBA1646
		NO EVENT		2245	aAF2233
		NO EVENT (early 5/27)		0023	dAF2236
<u>27</u>		NO EVENT		0854	aAF0842
Sat		NO EVENT		1057	aBA1045
		NO EVENT		(1208)*	(aBA1210)*
		NO EVENT		1428	dBA1241

## NOVA SCOTIA - MAY

DATE 1978	C,A,N CODE	PLACE OF EVENT	ACTUAL TIME OF EVENT ADT	CALCULATED TIME ADT	ACTUAL ARR/DEP TIME EST
		NO EVENT		1459	dAF1312
	N	Brass Hill	1547	(1511)*	(dAF1315)*
		NO EVENT (early 5/28)		0020	dAF2233
<u>28</u> Sun		NO EVENT		0848	aAF0836
	N	Middleton, 3b	1145	1109	aBA1057
	N	Baccaro	1330		
		NO EVENT		1424	dBA1237
		NO EVENT		(1441)*	(dBA1245)*
	N	Brass Hill (possible duplicate 4/17)	1547	1505	dAF1318
	N	Doctor's Cove	1700		
		NO EVENT		(1753)*	(aAF1755)*
<u>29</u> Mon		NO EVENT		0909	aAF0857
		NO EVENT		1027	(aBA1015)*
		NO EVENT		(1208)*	(aBA1210)*
		NO EVENT		1470	dBA1233
	A	Cape Sable Light	1455		
		NO EVENT		(1511)*	(dAF1315)*
		NO EVENT		1521	dAF1 334
<u>30</u> Tue	C	Ingomar	0850	0851	aAF0839
	A	Cape Sable Light Newellton	0943 1000		
	C	Northeast Harbour, rw Ingomar, rw	1015 1015	1009	aBA0957
	C	Northeast Harbour, rw	1445	1438	dBA1251
		NO EVENT		(1441)*	(dBA1245)*
		NO EVENT		1507	dAF1320
	N	Baccaro Coffinscroft, rw	1655 1655		
<u>31</u> Wed	N	Newellton	0830		
		NO EVENT		0917	aAF0905
		NO EVENT		1042	aBA1030
		NO EVENT		1420	dBA1233
		NO EVENT		1504	dAF1317
		NO EVENT		(1753)*	(aAF1755)*
	N	Northeast Point	2030		
	N	Brass Hill	2055		

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