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Acoustics • Shock • Vibration • Signal Processing **January 2007 Newsletter**

שָׁלוֹם *Shalom*

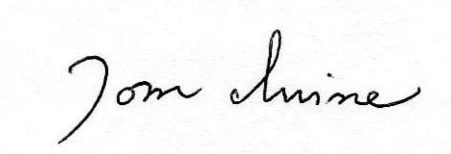
Meteors have fascinated men throughout the ages. Some cultures have regarded meteors of harbingers of cataclysms or other great events. Meteorites have also been used for religious worship.

In addition to a dazzling light display, some meteors emit a sizzling sound which allows observers to hear and see them at the same time. This is a paradox which defies conventional physics, but a plausible explanation is given in the first article.

The second article discusses the shofar, a Jewish trumpet made from a ram's horn. The use of the shofar for Rosh Hashanah and other holidays goes back 5000 years to the earliest books of the Bible.

Pray for the peace of Jerusalem: they shall prosper that love thee. Psalms 122:6

Sincerely,



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Feature Articles

Electrophonic Sound by Tom Irvine

Figure 1. Aurora Borealis

During the 2001 Leonid meteor shower photographer Frank S. Andreassen of Norway captured this image of two things that produce mysterious "electrophonic" sounds: auroras and meteors.

Introduction

A bolide is a type of exploding meteorite. It can be a natural source of sound. It can produce a sonic boom severe enough to shatter windows, as reported in the Vibrationdata Newsletter, May 2002. A bolide can also produce a particular type of emission called an electrophonic sound which is the topic of this article.

The Aurora Borealis can also generate electrophonic sound, which is closely related to the very low frequency (VLF) electromagnetic radiation discussed in the Vibrationdata Newsletter, June 2005. The “Auroral Chorus” reported in the 2005 article requires a special radio receiver and antenna system which transforms the VLF energy into audible sound.

On the other hand, electrophonic sound from a bolide or Aurora may become audible via ordinary objects, including natural ones. Simple materials like aluminum foil, thin wires, pine needles, dry or frizzy hair, or even eyeglasses can intercept and respond to a VLF field.

Radio waves induce currents in these materials, which function as electrical conductors or as “dielectric media.”

"Strong, low-frequency currents can literally shake ordinary objects," explains Dennis Gallagher, a space physicist at the NASA Marshall Space Flight Center. "When things shake, they launch vibrations into the air, which is what we hear."

VLF radio waves oscillate at frequencies between a few kHz and 30 kHz, propagating at the speed of light. Higher-frequency radio waves, like TV transmissions or FM radio broadcasts, oscillate much too fast (hundreds of millions of times per second) to substantially shake conductors. Furthermore, the resulting MHz-frequency sound waves are far above the frequency range of a human ear, which is typically 20 kHz.

Meteor Case Histories

Audible electrophonic sounds are somewhat rare, however.

An account from China in 817 AD tells of a meteorite which produced a noise "like a flock of cranes in flight."

Ninety minutes before sunrise on April 7, 1978, a meteor appeared over Eastern Australia. It streaked across the sky for about 20 seconds leaving a bright trail that turned night into day, before finally exploding into glowing fragments that vanished into the sea. This meteor was just one of thousands that enter the atmosphere every year. Yet dozens of witnesses in Newcastle and Sydney reported that it emitted an unearthly soundtrack of hisses, crackles and pops, before it blew apart.

Figure 1. Leonid Meteor Shower

(Courtesy of Paulo Raymundo)

The Leonid meteor shower of November 18, 2001 also generated exotic sounds.

"I am sure I could hear several of the meteors," recalled Karen Newcombe, a Leonid watcher from San Francisco. "Several times when a Leonid with a persistent debris train flew directly overhead, I heard a faint fizzing noise [instantly]." There was no delay between the sight and the sound.

"How is that possible when the meteor was so many miles above my head?" she wondered.

A Paradox

A baffling thread in these anecdotes is that the sound seems to travel at the speed of light and even faster in some cases than the meteorites own visible light.

Sir Edmund Halley[1] in 1719 attributed the reports to the observers' imagination.

Halley collected accounts of a widely-observed fireball over England. Many witnesses, wrote Halley, "[heard] it hiss as it went along, as if it had been very near at hand."

Yet Halley's calculated that the meteor was at least "60 English miles" high.

Sound takes about five minutes to travel such a distance, while light can do it in a fraction of a millisecond. Rounding up, light travels almost one million times faster than sound.

Halley could not explain why sky watchers simultaneously heard and saw the meteor. He finally dismissed the reports as "pure fantasy." This view held sway for centuries.

Theory

Australian researcher Colin Keay uses the term "magnetic spaghetti" to describe a theory he developed in the early 1980s.

Keay said, "[I was inspired by] Fred Hoyle's sunspot theory in which energy is trapped in twisted magnetic fields," he says. Magnetic fields that suddenly untangle -- snapping back like stretched rubber bands -- can trigger solar flares:

[1] Halley is best known for using Newton's law of gravitation to successfully predict that a comet seen in 1682 would return in 1758. The returning comet was then named after Halley.

violent blasts of electromagnetic radiation and energetic particles.

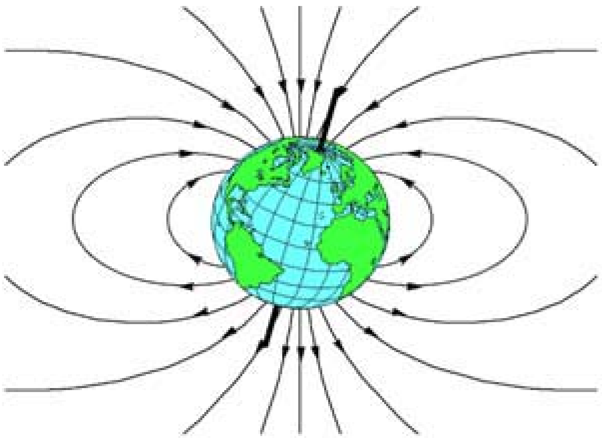

Figure 3. Earth's Magnetic Field Lines

The magnet field is caused by circulating electrical currents in the Earth's molten metallic core

A meteor plunging earthward encounters pressure and friction from the atmosphere. The meteor leaves a turbulent trail of electrically charged particles, or plasma[2], which becomes entangle in Earth's invisible but potent magnetic field lines. The trapped particles distort the field lines which become twisted like strings of cooked spaghetti.

Keay explains that the plasma cools eventually. Electrons return to the atoms from which they were earlier ripped, and the gas becomes neutral again. Magnetic fields are then suddenly free to straighten out. The abrupt rebound produces the low frequency radiation waves.

The waves travel at the speed of light and are then converted into sound when they interact near the ground with materials that serve as "dielectric media" or "transducers."

NASA space physicist Dennis Gallagher says that this theory is plausible and that it is supported by laboratory experiments.

Gallagher added, "I think what makes this exciting is that we're talking about a phenomenon that has been experienced by people for perhaps thousands of years. Even in modern times folks who reported hearing such sounds were ridiculed. It was only about 25 years ago that Keay was able to do the research and legitimize the experiences of all those generations of people."

"It shows there are still wonders in nature yet to be recognized and understood. We should take this experience with meteors as reason to open our minds to what may yet be learned."

Auroral Sound

Auroral sounds have been reported for centuries, although this would seem to be impossible.

Linda Hasselstrom was dazzled by waves of blue auroral light sweeping up from the horizon and meeting at a focal point nearly directly overhead of her family's cattle ranch in South Dakota, on March 13, 1989. As the sky blazed, with the blue waves and crimson streamers, she heard:

> "...a distant tinkling, like bells. It came again, louder, just as a curtain of green light swept the entire width of the sky from north to south. Each time green flushed the sky, the bells rang, the sound softening to a gentle tinkle as the light died."

Aurora activity occurs at altitudes above 50 miles. A near vacuum prevails above this altitude. Sound cannot propagate in a vacuum, because it requires a physical

[2] Plasma is an ionized gas. It is known as the fourth state of matter. It does not conform to the gas laws of conventional thermodynamics.

medium for transmission. Again, electrophonic sound seems to be the best explanation.

Nuclear Explosions

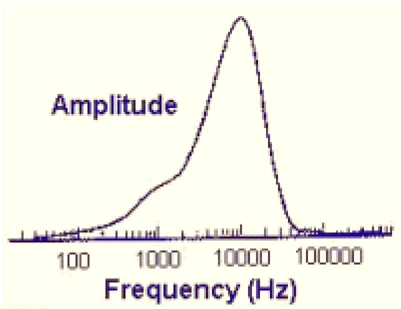

Figure 4.

Nuclear explosions are also known to release VLF radio waves, which are reportedly "heard" by soldiers in nearby bunkers. This VLF spectrum from such an explosion peaks at 12 kHz.

Space Shuttle Reentry

Figure 5.

Orbiter Reentry, Artist's Rendition

The orbiter encounters a very energetic pressure wave at its leading surfaces upon reentry. The energy density is sufficient to cause atmospheric molecules to dissociate, and their component atoms to become ionized. The vehicle thus descends in a superheated shroud of incandescent, electrostatically-charged plasma. This plasma is capable of generating VLF radiation, which can be converted to electrophonic sound at or near the ground.

The spectacular reentry of the Space Shuttle *Discovery* in November 1984 was observed by many Texans in the pre-dawn sky. Ben and Jeannette Killingsworth observed the orbiter streak across the sky. They both heard an unmistakable "swishing noise" as it passed south of their rural Galveston County home. Ben graphically described the sounds as "like a skier coming down a slope."

The sonic boom came several minutes later, but the swishing sound occurred simultaneously with the visual apparition.

Shofar Acoustics by Tom Irvine

Figure 1.

Introduction

A shofar is a trumpet-like instrument made from the horn of a ram or other kosher animal.

Some Yemenite shofars are made from the horn of a kudu or ibex. A kudu is an antelope. An ibex, also called steinbock, is a type of wild mountain goat.

The shofar cannot be made from a cow's horn, however, because of the golden calf idol which the children of Israel constructed while wandering in the Sinai desert.

The shofar is sounded at Rosh Hashanah, the Jewish New Year. It is not blown, however, if Rosh Hashanah falls on the Shabbat. The shofar is also sounded at Yom Kippur, the "Day of Atonement."

In addition, the shofar was sounded in Biblical times as an

- Alarm for war
- Signal of peace
- Announcement of the New Moon or Rosh Chodesh (Psalms 81:3)

It was also played for a variety of processions and solemn feasts.

The shofar was sounded when Moses received the Ten Commandments at Mount Sinai (Exodus 19:16-19 & 20:18).

In post-biblical times, the sounding of the shofar has been limited to special holidays since the destruction of the second temple in Jerusalem by Roman legions in 70 A.D. Music and the playing of the shofar had been a prominent part of temple worship. Limiting the use of the shofar became a means of mourning for the lost temple.

Nevertheless, Rabbi Shlomo Goren sounded a shofar at the Western Wall to commemorate the reunification of Jerusalem in 1967.

Symbolism

According to author Leo Rosten,

> "The bend in the shofar is supposed to represent how a human heart, in true repentance, bends before the Lord. The ram's horn serves to remind the pious how Abraham, offering his son Isaac in sacrifice, was reprieved when God decided that Abraham could sacrifice a ram instead. The man who blows the shofar is required to be of blameless character and conspicuous devotion; he must blow blasts of different timbre, some deep, some high, some quavering.

Furthermore Rabbi Abbahu said:

> "Why do we sound the shofar? Because the Holy One, blessed be God, said: Blow me a ram's horn that I may remember to your credit the

binding of Isaac, the son of Abraham, and I shall account it to you as a binding of yourselves before Me. The Torah tells us: Abraham looked up and behold, he saw a ram caught in the thicket by its horns [Genesis 22:13].

This teaches us that the Holy One, blessed be God, showed our ancestor Abraham the ram tearing himself free from one thicket and becoming entangled in another.

Said the Holy One, blessed be God, to Abraham: Thus are your children destined to be caught in iniquities and entangled in misfortunes, but in the end they will be redeemed by the horns of a ram.

Therefore the prophet Zechariah said of the time of redemption: And the Lord shall be seen over them, and his arrow shall go forth like the lightning; and the Lord God shall blow the shofar, and shall move in stormy winds of the south [Zechariah 9:14]. "

Battle of Jericho

Seven priests each blowing a ram's horn brought down the walls of Jericho under the leadership of Joshua, according to a Bible story (Joshua 5:13-6:27). The priests were accompanied by a chorus of shouting Israelites.

The shofar was commonly taken out to war so the troops would know when a battle would begin. The person who would blow the shofar would call out to the troops from atop a hill. All of the troops were able to hear the call of the shofar from their position because of its distinct noise.

Rosh Hashanah

The Torah or Bible refers to this holiday as "The Day of the Blowing of the Shofar." It represents a call to repentance.

Leviticus Chapter 23:

[23] And the LORD spake unto Moses, saying,
[24] Speak unto the children of Israel, saying, In the seventh month, in the first day of the month, shall ye have a sabbath, a memorial of blowing of trumpets, an holy convocation.

A total of 100 notes are sounded each day. The sounds represent a person weeping or groaning. There are four different types of shofar notes:

Tekiah	-	a 3 to 5 second sustained bass note.
Shevarim	-	three 1-second notes rising in tone.
Teruah	-	a series of short, staccato treble notes extending over a period of about 3 seconds.
Tekiah Gedolah	-	the final blast in a set, which lasts 4 seconds minimum.

The dates for upcoming holidays are

Year	Jewish Year	Rosh Hashanah (begins at sundown)
2007	5768	Sept. 12
2008	5769	Sept. 29
2009	5770	Sept. 18
2010	5771	Sept. 08
2011	5772	Sept. 28
2012	5773	Sept. 16
2013	5774	Sept. 04
2014	5775	Sept. 24

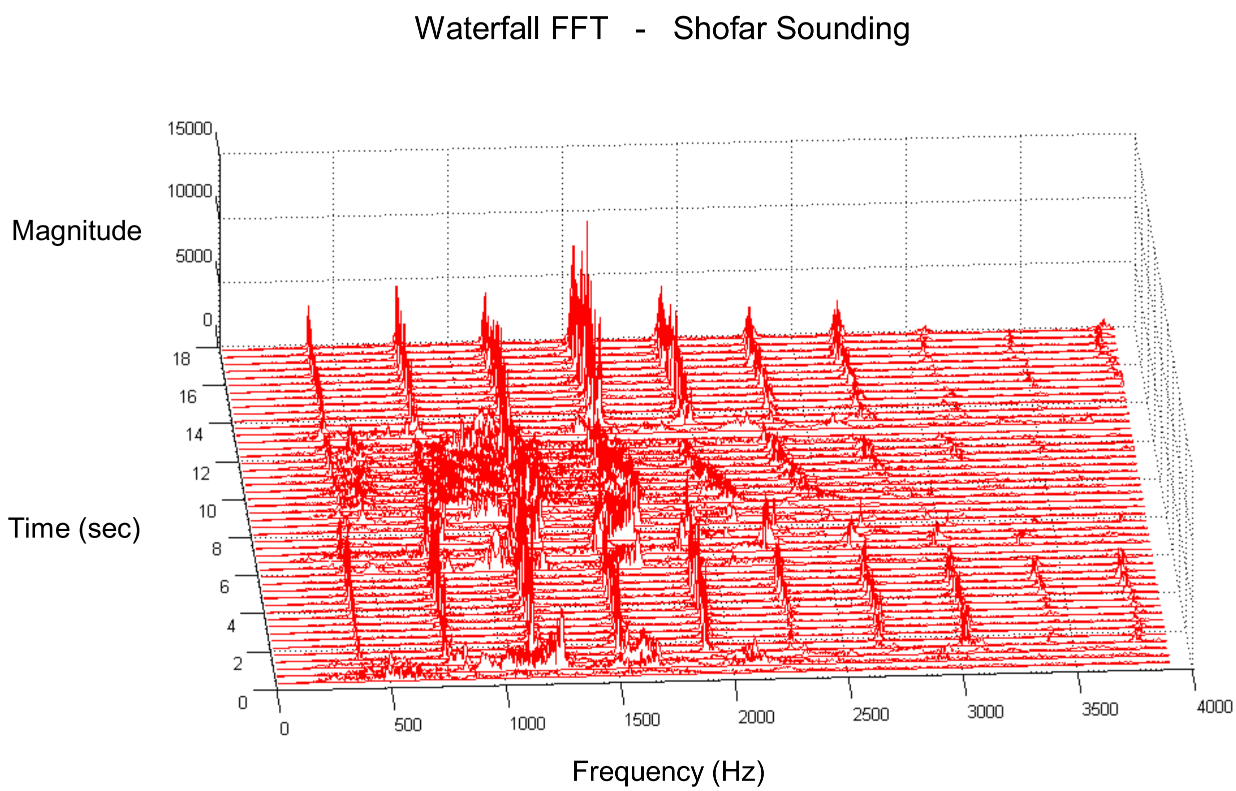

Figure 2.

The sounding of a typical shofar is shown in Figure 2 as a waterfall FFT.

The fundamental frequency is 376 Hz, which is slightly higher than an F# note. Integer harmonics are also present.

The higher harmonics of the Teruah staccato notes sweep downward in frequency, as shown from about 9 to 13 seconds.

There is no standard length for a shofar horn. Thus, individual horns vary in terms of pitch.

Seiches in Pools and Lakes Caused by Earthquakes by Tom Irvine

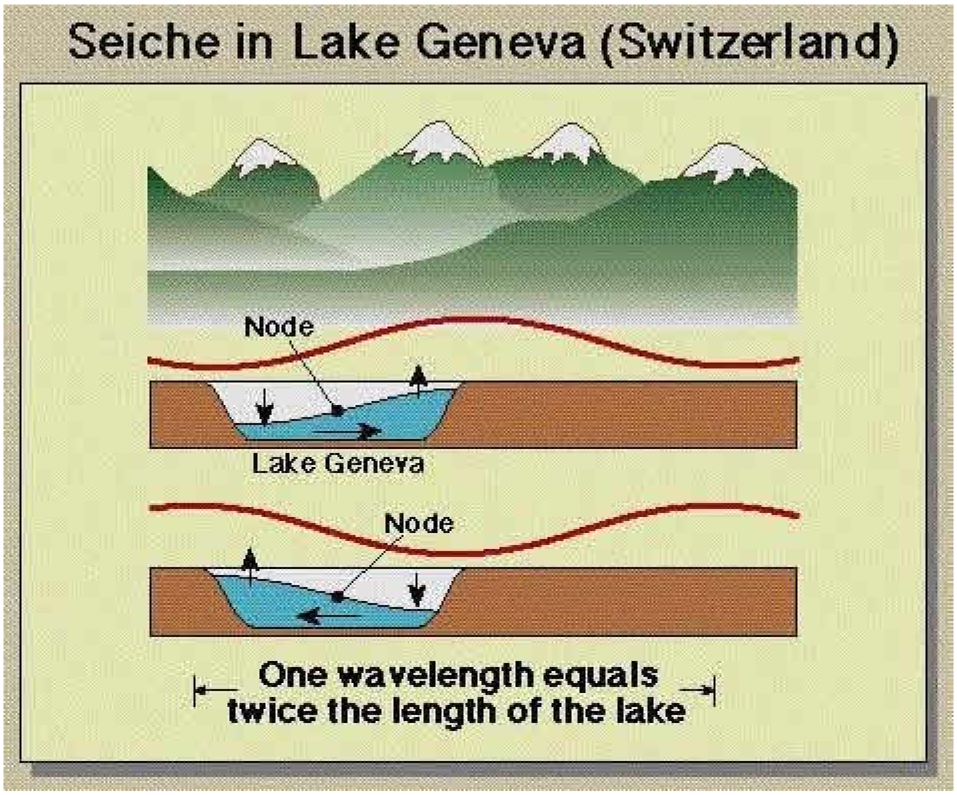

Figure 1.

Introduction

Water in an enclosed basin rocks rhythmically back and forth from one end to the other. The period of this oscillation depends on the basin's geometry. In a cylindrical tank, this rocking motion is called "slosh." In a natural basin, it is called a "seiche." This term is pronounced as "saysh." It is an old Swiss French word meaning "to sway."

A seiche may be exited by wind, tides, or seismic events.

The Vibrationdata Newsletter of February 2002 discussed the seiches in the Bay of Fundy, Lake Geneva and other large bodies of water.

This purpose of this article is to consider observations of seiche oscillation in pools and lakes due to earthquakes. The accounts are somewhat anecdotal because measured data is not readily available. Furthermore, the oscillations may be due to the direct effects of the ground motion or indirectly caused by landslides in the case of a lake.

Table 1. Seiche Periods	
Body	Period
Typical Bathtub	1 sec
Typical Residential Swimming Pool	4 to 5 sec
Hilo Bay, Hawaii	30 min
Lake Geneva, Switzerland	73 min
Bay of Fundy, Nova Scotia	13.3 hour

Table 2. Seiches Excited by Earthquakes			
Year	M	Epicenter	Seiche Observations
1755	8.7	Lisbon, Portugal	Seiches occurred in canals in Scotland and Sweden.
1950	8.6	Chayu-Upper Assam, India	Seiches occurred as far away as Norway and southern England.
1964	9.2	Prince William Sound, Alaska	The "Good Friday" earthquake caused sloshing in swimming pools as far away as Puerto Rico.
1985	8.0	Michoacan, Mexico	The swimming pool at the University of Arizona in Tucson lost water from sloshing caused by the quake, although the epicenter was 2000 km (1240 miles) away.
1989	6.9	Loma Prieta, California	"I was at home in eastern Sacramento County and I felt nothing, but, for some reason, had been watching ESPN and saw the earthquake on TV. I ran to see water sloshing out of our pool." - Matt (Reference 1)
1994	6.7	Northridge, California	Swimming pools throughout Southern California overflowed. The excitation frequency tended to be at or near the slosh fundamental frequency of these pools.
2002	7.9	Denali, Alaska	See Note 1
2004	9.1	Indian Ocean near Northern Sumatra	The earthquake caused seiches in standing water bodies throughout India, Bangladesh, Nepal and Thailand. One person was drowned after being swept away by a particularly energetic seiche in the Jalangi River in the Nadia district to the north of Kolkata in West Bengal.

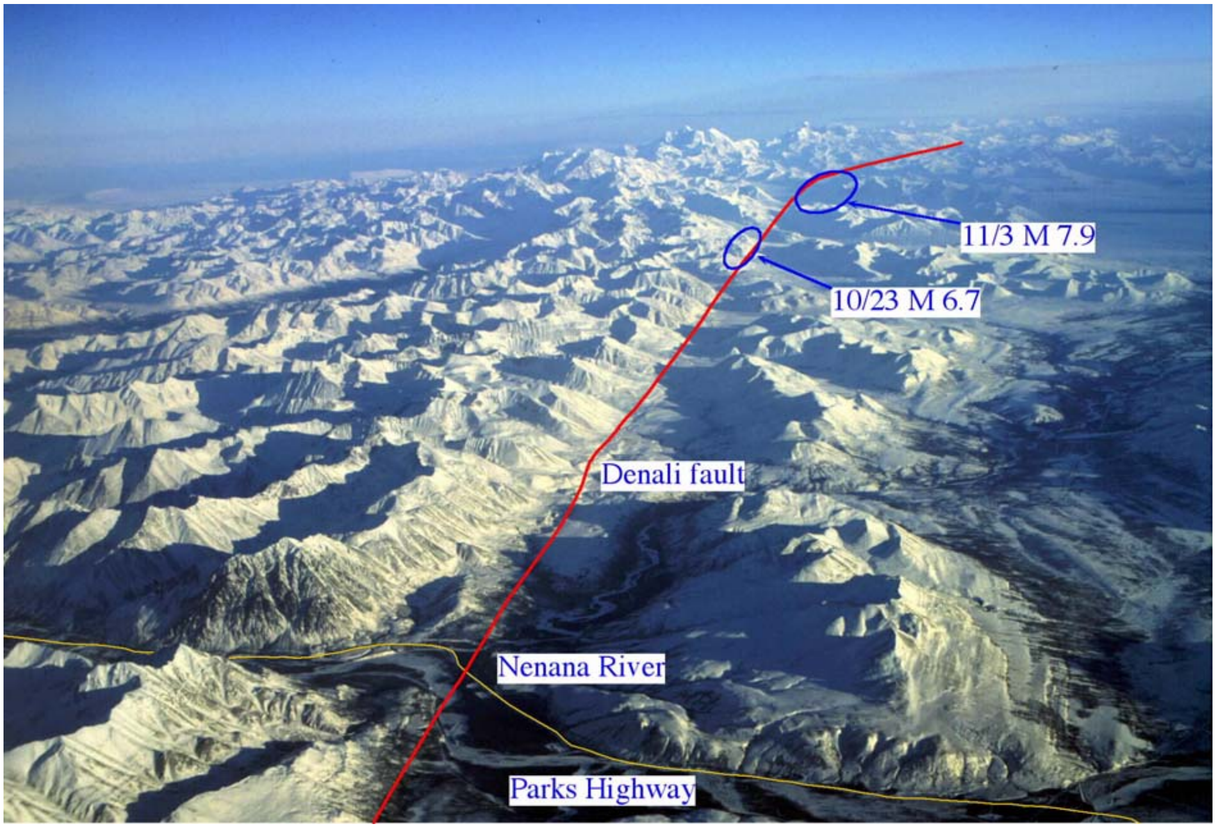

Figure 2. Denali Fault

Note 1, Denali National Park Quake, 2002

"When you have an earthquake of this size, it generates what we call surface waves which are energy that travel through the earth's crust and these waves cause disturbances that can be looked upon as ripples or disturbances" in water, said Dale Grant, a geophysicist with U.S. Geological Survey's National Earthquake Information Center in Golden, Colo.

In Mandeville, across Lake Pontchartrain from New Orleans, Carol Barcia, 47, was sitting with neighbors on the deck of her house around 5 p.m. when she saw boats bounce around.

"We were just sitting outside on our back deck, just relaxing, and we noticed the sail boats started leaning over, going back and forth, and the boats' lines were just banging up and down. My boat was banging up against the dock. My neighbor's boat broke a line," Barcia said. (Reference 2)

"One poor guy across the canal from us fell off his sail boat," Barcia, a pharmaceutical representative, said.

She said a neighbor rode a boat over Bayou Castine and helped the man out of the water.

Similar stories were reported in other states, Grant said.

References

1. http://geology.about.com/cs/eq_regional/a/aa101799a.htm
2. http://www.usatoday.com/news/nation/2002-11-03-alaska-quake_x.htm